Upper Mississippi River Nine-Foot Channel Project,
Lock and Dam Nos. 24 through 27
Clarksville, Missouri
~~St. Louis, Missouri~~ Pike County, Missouri
St. Louis County, Missouri

HAER No. MO-50

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~~PHOTOGRAPHS~~

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
Rocky Mountain Regional Office
National Park Service
U. S. Department of the Interior
P.O. Box 25287
Denver, Colorado 80225

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HISTORIC AMERICAN ENGINEERING RECORD

Upper Mississippi River Nine-foot Channel Project, Lock and Dam Nos. 24 through 27

HAER No. MO-50

Location:	Clarksville, Missouri, to St. Louis, Missouri (U.S. Army Corps of Engineers, St. Louis District)
Date of Construction:	1927-1940, 1948-present
Architect/Engineer:	U. S. Army Corps of Engineers
Present Owner:	U. S. Government (St. Louis District, U.S. Army Corps of Engineers)
Present Use:	River navigation and control

Significance:

The Upper Mississippi River Nine-Foot Channel Project represents one of the largest and most ambitious river improvement projects ever constructed in the United States. The projeet's origins date to the 1920s and the efforts of Upper Midwest commercial interests to improve their access to markets. During the early years of the Great Depression, the project became transformed into a massive public works program intended to relieve local and regional unemployment.

The locks and dams that eomprise the projeet constitute seminal developments in the technological history of American river navigation projects. The project pioneered the use of non-navigable movable dams in the United States. Designers and engineers from the U.S. Army Corps of Engineers committed themselves to a foreign technology, by their decision to incorporate roller gates into the majority of the project's dams and, more importantly, developed new and improved versions of the simpler and more reliable Tainter gate at such a rapid rate that, by the end of the 1930s, roller gates had become a passe' technology.

The successful completion of the Nine-Foot Channel Project transformed the Upper Mississippi River into an intra-continental canal, providing a fully navigable interior river system throughout the Midwest. The project significantly altered the environment of the Upper Mississippi, but it also served as an impetus for the improvement of drinking water and sewage disposal systems in towns and cities located along the river. Additionally, the project provided new recreational opportunities to the general public.

Historian: Patrick W. O'Bannon, July 1989

ACKNOWLEDGEMENTS

John Milner Associates, Inc. (JMA) wishes to acknowledge the extraordinary Assistance received during the course of this project from employees of the U.S. Army Corps of Engineers, St. Louis District. F. Terry Norris, District Archeologist, served as our local contact in St. Louis and provided introductions to many Corps personnel. The lockmasters at the individual facilities, J. Daniel Buckley (Lock and Dam No. 24), Fred I. Troutner, Jr. (Lock and Dam No. 25), Don Schrader (Lock and Dam No. 26), and Ken Strong (Lock No. 27), all freely opened their files and graciously lent irreplaceable photographs and drawings for our study. Likewise, in the St. Louis District Office, William R. Sutton, Project Manager for Lock and Dam No. 26R, provided JMA with a wealth of photographs and technical journals, and permitted virtually unlimited access to this ongoing construction project. Without the assistance of these gentlemen, completion of this project would have been greatly complicated.

Myrna F. V. Geselbracht of the Central Plains Regional Branch of the National Archives, located in Kansas City, Missouri, provided access to the dozens of unprocessed boxes of archival material deposited with the National Archives by the St. Louis District. John Daniel of the National Personnel Records Center in St. Louis, Missouri, facilitated research in the personnel records of former civilian Corps of Engineers' employees.

Carolyn Clark of the Rocky Mountain Regional Office of the National Park Service served as contracting officer for the project. William Patrick O'Brien of the Rocky Mountain Regional Office's Division of Cultural Resources served as the contracting officer's technical representative, and provided extraordinary assistance.

Historic American Engineering Record Documentation
Lock and Dam Nos. 24-27
Upper Mississippi River 9-Foot Channel Project
U.S. Army Corps of Engineers, St. Louis District

FORWARD

The following Historic American Engineering Record history documents Lock and Dam Nos. 24-27. These complexes comprise portions of the 26-unit Upper Mississippi River 9-Foot Channel Project constructed between St. Paul, Minnesota and St. Louis, Missouri under the supervision of the U.S. Army Corps of Engineers between 1927 and 1940.[1]

The report is divided into three major sections. The first section, "Administrative History," provides a brief political and economic overview of the project's conception, construction, and implementation. The "Technological History" traces the development of the technologies employed in the design and construction of the lock and dam complexes. This section includes detailed construction histories for several elements of the project that illustrate the evolutionary nature of the technological and administrative aspects of the project in the St. Louis District of the U.S. Army Corps of Engineers. The

[1]Lock and Dam No. 27 were constructed after 1940, and comprised the final link in the navigation system. Lock and Dam No. 26R, which is presently nearing completion, is a replacement for the deteriorated and overtaxed Lock and Dam No. 26.

third section of the report consists of inventories, in outline format, of each individual lock and dam complex. These inventories include information on construction histories and methods, unique and significant design considerations, and a review of specific technological and engineering elements within each complex. Also included in this section are descriptions of the configuration and appearance of each complex and chronologies of alterations and additions made since the onset of daily operations.

Historic American Engineering Record Documentation
Lock and Dam Nos. 24-27
Upper Mississippi River 9-Foot Channel Project
U.S. Army Corps of Engineers, St. Louis District

INTRODUCTION

In October 1988 John Milner Associates, Inc. (JMA) began the documentation and recordation, to Historic American Engineering Record (HAER) standards, of Lock and Dam Nos. 24, 25, 26, 26R, and 27 on the Upper Mississippi River. This project was conducted for the Rocky Mountain Regional Office of the National Park Service and the St. Louis District of the U.S. Army Corps of Engineers, which owns and operates the five lock and dam complexes.

Lock and Dam Nos. 24, 25, and 26 constitute part of the Corps of Engineers' Upper Mississippi 9-Foot Channel Project, a massive navigation improvement and public works program undertaken between 1927 and 1940 that provided a 9-foot deep channel from St. Paul, Minnesota to Alton, Illinois, just above the mouth of the Missouri River. The other elements of this project, located within the Corps of Engineers' St. Paul and Rock Island Districts, have previously been recorded to HAER standards.[2]

[2]William Patrick O'Brien, "Upper Mississippi River 9-Foot Channel Project Locks and Dams 3-10: An Inventory for the U.S. Army Corps of Engineers, St. Paul District" (Denver: Rocky Mountain Regional Office, National Park Service, 1987); Rathbun Associates,

Lock No. 27, and the associated Chain of Rocks Canal, dates from the late-1940s and early-1950s. This installation provided a dependable 9-foot channel from Alton, Illinois to St. Louis, Missouri. Dam No. 27, also known as the Chain of Rocks Dam, was constructed separately from Lock No. 27 in the early 1960s to improve low water navigation below Lock and Dam No. 26. Lock and Dam No. 26R is located two miles below Lock and Dam No. 26, which it is intended to replace. This installation, authorized by Congress in 1969, is presently under construction. Neither Lock and Dam No. 27 nor 26R can technically be considered part of the 9-Foot Channel Project as it was originally conceived, designed, and implemented. Nevertheless, these two installations serve essentially the same purpose as their predecessors and provide an opportunity to study the continued development of lock and dam technology as applied on the Upper Mississippi River.

"Historic American Engineering Record Documentation -- Lock and Dam Systems 11-22, Upper Mississippi River 9-Foot Channel Project -- U.S. Army Corps of Engineers, Rock Island District" (Denver: Rocky Mountain Regional Office, National Park Service, 1988).

ADMINISTRATIVE HISTORY

The Upper Mississippi River extends from the head of practical navigation, at St. Paul, Minnesota, downstream for over 650 miles to the mouth of the Missouri River. The federal government assumed responsibility for the elimination of troublesome spots in the river channel as early as 1837. This work included dredging, removal of snags and other hazards, and the provision of an improved channel at rapids and other obstacles. The rather shallow depth of the river, which averaged approximately three feet, and at certain seasons amounted to as little as one foot in the two hundred miles below St. Paul, resulted in a continual series of minor improvements and remedial work.[3]

In June 1878 Congress authorized the United States Army Corps of Engineers to undertake its first major navigation improvement project on the Upper Mississippi, the provision of a 4.5-foot deep channel from St. Paul to St. Louis. In 1907 Congress, under pressure from river improvement organizations centered in

[3]Hibbert M. Hill, "Developing the Upper Mississippi: Plans for Deepening Existing Channel," Civil Engineering, 1 (December 1931):1352; Charles P. Gross and H. G. McCormick, "The Upper Mississippi River Project," The Military Engineer, 33 (July-August 1941):313.

the Minneapolis/St. Paul area, authorized the Corps to maintain a 6-foot channel of suitable width.[4]

Both the 4.5-foot channel and the 6-foot channel were achieved by a system of wing and closing dams, augmented by almost continual dredging. Closing dams prevented the river from leaving the main channel and entering sloughs and side-channels. Hundreds of wing dams constricted the flow of the river, speeding the current and providing a clear channel of the authorized depth. Both the closing dams and wing dams were relatively simple structures, generally of brush or timber construction.[5]

The 6-foot channel project, which was never fully completed, was outmoded almost from the moment of its authorization. The Middle and Lower Mississippi River, below St. Louis, maintained a 9-foot channel, as did the Ohio River. This discrepancy between channel depths meant that goods traveling on the Upper Mississippi required transhipment at St. Louis or Cairo,

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[4]Hill, "Developing," p. 1352; Gross and McCormick, "Upper Mississippi River Project," 311; Philip V. Scarpino, Great River: An Environmental History of the Upper Mississippi, 1890-1950 (Columbia: University of Missouri Press, 1985), pp. 166-167.

[5]P. S. Reinecke, "The Rhine and the Upper Mississippi," The Military Engineer, 30 (May-June 1938):169; Scarpino, Great River, pp. 166-167; Raymond H. Merritt, The Corps, the Environment, and the Upper Mississippi River Basin (Washington: Government Printing Office, 1984), p. 35.

Illinois. Lobbying for a 9-foot channel on the Upper Mississippi began in earnest in the early 1920s. Supporters of the project argued that completion of the Panama Canal had placed the Midwest at a competitive disadvantage by lowering intercoastal shipping rates below the railroad rates paid by midwesterners. The Interstate Commerce Commission compounded this disadvantage in 1925, by raising railroad rates between St. Paul and St. Louis one hundred percent. Secretary of Commerce Herbert Hoover summed up the prevailing situation in a 1926 speech, noting that while the Panama Canal had brought New York \$2.24 closer to the Pacific Coast it had driven the Midwest \$3.36 further away from West Coast markets.[6]

The federal government began to investigate the viability of a 9-foot channel on the Upper Mississippi in the mid-1920s. The government-owned Inland Waterways Corporation operated barges on the Upper Mississippi beginning in 1926, and this experience reinforced impressions concerning the inadequacy of the incomplete 6-foot channel.[7]

In January 1927 Congress authorized the Corps of Engineers to survey the river from the mouth of the Missouri River to

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[6]Merritt, <u>The Corps</u>, p. 53.

[7]Hill, "Developing," p. 1352; Merritt, <u>The Corps</u>, p. 53.

Minneapolis for the purpose of securing a 9-foot channel. In May 1929 the Chief of Engineers appointed a survey board that included the district engineers of the three affected districts, St. Paul, Rock Island, and St. Louis, as well as the district engineer from the Louisville District, whose office was then completing construction of a 9-foot channel on the Ohio River.[8]

The survey board issued an interim report to the War Department in December 1929 that outlined prevailing economic conditions on the Upper Mississippi, described the existing river conditions, provided three alternative means for attaining a 9-foot channel, and recommended the complete canalization of the river by means of locks and dams as "the only reliable and most economical method for obtaining a depth of 9 feet for a reasonably free and unrestricted channel. . ." On the basis of this incomplete interim report, formally issued to Congress in February 1930,

[8]Merritt, The Corps, p. 53; Rathbun Associates, "HAER Documentation," p. 21. The Rathbun Associates report provides a thorough discussion of the administrative adjustments made by the Corps of Engineers prior to the authorization of a 9-foot channel project on the Upper Mississippi. This report will limit itself to a general outline of these administrative changes, and will not focus upon the bureaucratic and political nuances of these changes.

Congress authorized the projected $150 million canalization of the Upper Mississippi in July 1930.[9]

The Corps of Engineers appear to have anticipated Congress' authorization of the 9-foot channel project as early as October 1929. In that month the Corps broke the St. Paul, Rock Island, and St. Louis Districts away from the Western Division and created the Upper Mississippi Valley Division, a new administrative entity intended to supervise activities in the three districts. Lieutenant Colonel George R. Spaulding, a member of the 9-foot channel survey board and former District Engineer of the Louisville District, became Division Engineer. Spaulding named William H. McAlpine, his principal civilian assistant in Louisville, Head Engineer of the new division. By the end of November 1929 Spaulding and McAlpine had begun reassembling the Louisville District design team, which between 1910 and 1929 designed the Ohio River 9-Foot Channel Project, in the St. Louis headquarters of the new Upper Mississippi Valley Division.[10]

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[9]U.S. Congress, Mississippi River, Between Mouth of Missouri River and Minneapolis, Minn. (Interim Report), House Doc. 290, 71st Cong., 2nd sess. (1930), pp. 1-8, 37. Hereafter cited as House Doc. 290.

[10]Rathbun Associates, "HAER Documentation", pp. 22-23.

In December 1930 the survey board submitted its final report to the Chief of Engineers. This report, submitted to Congress in December 1931 and published in early 1932, reiterated and expanded upon the findings and conclusions of the interim report. The report concluded that canalization of the river by means of locks and dams provided the most economical and dependable means for securing a 9-foot channel. The existing system of dredging and regulation could not provide the required channel, while development of a system of reservoirs could provide a 9-foot channel in some locations, but at a greater expense than the estimated $124 million required for canalization.[11]

The report called for construction of twenty-four new locks and dams below Hastings, Minnesota and the incorporation of three existing structures into the project. The various structures were assigned to four categories on the basis of their importance to the project. Group A structures were needed immediately to care for existing commerce. Group B structures were necessary to provide a dependable 6-foot channel. Group C and Group D structures were additional works needed to ultimately secure a dependable 9-foot channel. All of the

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[11]U.S. Congress, Survey of Mississippi River Between Missouri River and Minneapolis, House Doc. 137 (2 parts), 72nd Cong., 1st sess. (1932), 1-10. Hereafter cited as House Doc. 137.

structures proposed for the St. Louis District were included in Group D, the lowest priority.[12]

The Upper Mississippi Valley Division assumed responsibility for the design of the major elements of the project, relegating design of "less critical" elements and construction supervision to the three districts.[13] Work began on two Group A structures, Lock and Dam Nos. 4 and 15, in 1931, but progressed slowly because of a shortage of funds, a direct consequence of the nationwide depression, and a series of lawsuits filed by railroad companies who feared that creation of the navigation pools would flood their tracks and objected to government-sponsored competition in the form of improvements to river navigation.[14]

In May 1933 hearings were held regarding the potential cancelation of the entire 9-Foot Channel Project. The Corps of Engineers, in a skillful display of bureaucratic flexibility, successfully recast the project, previously conceived of solely

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[12] Ibid., p. 11.

[13] Rathbun Associates, "HAER Documentation," p. 24.

[14] Ibid., pp. 25-27. The railroad suits were eventually resolved, and the Corps of Engineers received authorization to amend and change the details of the project as it saw fit, which eliminated the threat of many lawsuits and greatly accelerated the design and construction schedule.

as a means of improving navigation on the Mississippi, into an opportunity to provide thousands of jobs. This transformation of the project necessitated the construction of many individual structures simultaneously, to put the maximum number of men to work. This new goal forced the decentralization of the design process, with the role of the Upper Mississippi Valley Division diminishing in importance after mid-1933 and that of the three districts increasing. The design team assembled by Spaulding and McAlpine was greatly reduced in size. Spaulding received a new assignment and McAlpine was transferred to Washington, D.C. as head of the Engineering Section in the Office of the Chief of Engineers.[15]

McAlpine oversaw the design of only one Upper Mississippi River 9-Foot Channel Project structure, Lock No. 26, in the St. Louis District. Nevertheless, his design work, as manifested in the lock and dam installations constructed in the St. Paul and Rock Island Districts, provided prototypes for those constructed in the St. Louis District after his transfer to Washington. The Upper Mississippi Valley Division retained design responsibility for all major elements of the lock and dam installations constructed in the St. Louis District. A. Frederick Griffin, a 1914 civil engineering graduate of the Worcester Polytechnic

[15]Rathbun Associates, "HAER Documentation," pp. 35-39.

Institute in Worcester, Massachusetts, succeeded McAlpine as the Upper Mississippi Valley Division's Senior Engineer and assumed responsibility for design of the principal elements of Dam No. 26, Lock and Dam Nos. 24 and 25, and Lock No. 27.[16]

The St. Louis District oversaw all construction work at the individual installations and provided some minor design services. This work was performed by the District's Lock and Dam Section, established by District Engineer Major W. A. Snow in October 1933, prior to the advertisement for bids on Lock No. 26, the first 9-Foot Channel Project installation constructed in the district. Captain William W. Wanamaker, a 1922 graduate of the Missouri School of Mines in Rolla, Missouri, headed the section, which initially consisted of four civilian engineers, two draftsmen, and a clerk. Lawrence B. Feagin, a 1922 graduate of Vanderbilt University in Nashville, Tennessee, served as the Lock and Dam Section's Senior Engineer. Feagin was responsible for all engineering work at Lock and Dam Nos. 24-26, exclusive of the initial design work performed by the Upper Mississippi Valley Division.[17]

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[16]O'Brien, "Upper Mississippi River," p. 20; Rathbun Associates, "HAER Documentation," pp. 22-23; Personnel Records, Almern Frederick Griffin, National Personnel Records Center, St. Louis, Missouri.

[17]Personnel Records, William W. Wanamaker, National Personnel Records Center, St. Louis, Missouri; Personnel Records, John A. Adams, National Personnel Records Center, St. Louis, Missouri; Personnel Records, Lawrence B. Feagin, National Personnel Records

The 9-Foot Channel Project appears to have generated little local opposition within the St. Louis District. The principal concern voiced by residents of river communities concerned the impact of the navigation pools upon their sewage systems. Most of these systems constituted a significant source of local pride and served as physical manifestations of the river towns' participation in the urban improvement and reform movements that swept the United States during the decades following the 1893 World's Columbian Exposition in Chicago.[18]

Lock and Dam No. 26 represented the only instance in the St. Louis District in which a 9-Foot Channel Project installation affected a local sewage system. The Corps of Engineers designed and constructed interceptor sewers that carried the Piasa Street and State Street sewer outlets to a point below the locks, thus assuring that the increased river height that resulted from the creation of the navigation pool would not adversely effect the community's sewers.[19]

Center, St. Louis, Missouri.

[18]Lois Craig, et al., The Federal Presence: Architecture, Politics, and Symbols in United States Government Building (Cambridge: The MIT Press, 1978), pp. 210-214.

[19]St. Louis District, Corps of Engineers, "Final Report -- Lock and Dam 26, Mississippi River, Alton, Illinois, Part I -- Locks," pp. 63-64. Typescript draft on file at St. Louis District Office. Hereafter cited as "Final Report -- Lock and Dam No. 26, Part I."

The 9-Foot Channel Project vastly increased the amount of barge traffic on the Upper Mississippi. Since 1940, when the project was completed from St. Paul, Minnesota to Alton, Illinois, traffic on the Upper Mississippi increased from 0.5 percent to approximately 3.7 percent of all United States shipping.[20] The tonnage passing through Lock and Dam No. 26, the southernmost of the installations constructed in the St. Louis District during the 1930s, increased from 1.4 million tons per year in 1938 to 55 million tons in 1975.[21] This enormous increase in traffic severely taxed the operational capacity of the installation and ultimately led, with a variety of other factors, to the construction of a new facility, Lock and Dam 26R, just downstream from the original installation.

After 1940 only a single impediment prevented the maintenance of a dependable and reliable 9-foot channel extending from New Orleans to Minneapolis and up the Ohio to Pittsburgh. Known as the Chain of Rocks Reach, this obstruction consisted of a seven-mile long series of rock ledges north of St. Louis. In two locations these ledges extended from the west bank of the river completely across the channel, acting as natural weirs or

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[20] O'Brien, "Upper Mississippi River," pp. 23-24.

[21] Fredrick J. Dobney, <u>River Engineers on the Middle Mississippi</u> (Washington: Government Printing Office, n.d.), p. 150.

submerged dams, sharply increasing the fall of the river and the velocity of the current. At extreme low water the navigable depth was often reduced to as little as 5.5 feet, preventing full use of the 9-foot channel available above and below the reach.[22]

Proposals to bypass Chain of Rocks by means of a canal originated as early as 1904, all without result. In October 1938 Congress requested the Chief of Engineers to prepare a report recommending a plan for the improvement of the Chain of Rocks Reach. This report, submitted in December 1938 and printed as House Document No. 231, recommended construction of a bypass canal. Congress authorized the project in 1939; however, President Franklin D. Roosevelt vetoed the bill in view of the imminence of war. Congress reapproved the project in March 1945, and the President signed the bill into law. The Upper Mississippi Valley Division, regaining some of the authority it lost during the rush to turn the 9-Foot Channel Project into a public works program, designed the canal and the lock located near its lower end. St. Louis District Engineer

[22] Ibid., p. 114; R. E. Smyser, Jr., "Chain of Rocks Project Improves Navigation on Mississippi River," Civil Engineering, 17 (June 1947):16.

Colonel Rudolph E. Smyser, Jr. oversaw the actual construction work.[23]

The completion of Lock No. 27 coincided with a major boom period in the American economy. This complicates efforts to separate the economic impact associated with the completion of the locks from the general economic upswing of the period. Nevertheless, between 1947 and 1956 the amount of river traffic passing through the Port of St. Louis increased from 2.6 million tons to 7.4 million tons. At least a portion of this increase must be credited to the improved conditions for river traffic that resulted from the completion of Lock No. 27.[24]

Dam No. 27, also known as the Chain of Rocks Dam, resulted from the need to provide additional water in the pool below Lock and Dam No. 26. Designed and constructed by the St. Louis District, this fixed crest rock dam, completed in 1964, extends entirely across the Mississippi at Chain of Rocks.[25]

The administrative and political history of Lock and Dam No. 26R is ongoing. Authorized by the Secretary of the Army in 1969,

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[23]Dobney, River Engineers, p. 115; Smyser, "Chain of Rocks," p. 16.

[24]Dobney, River Engineers, p. 113.

[25]Ibid., p. 116.

this structure will ultimately replace Lock and Dam No. 26, which is seriously deteriorated and reached its practical capacity of 46.2 million tons per year in 1970. Planning for a replacement dam began in the Corps of Engineers' St. Louis District Office in 1970, however a court injunction resulting from parallel lawsuits filed by the Sierra Club, the Izaak Walton League and the Western Railroad Association, halted work in September 1974. The lawsuit charged that the environmental analysis of the project was inadequate and that the Congressional authorization, under the River and Harbor Act of 1909, applied only to maintenance work.[26]

The environmentalist opponents of the new facility fear that it represents an effort to promote a 12-foot channel in the Upper Mississippi. The design of Lock and Dam No. 26R meets the construction requirements for a 12-foot channel outlined in a 1972 Upper Mississippi River Comprehensive Basin Study, which declared a 12-foot channel not economically feasible above the mouth of the Illinois River. Railroad industry opposition to Lock and Dam No. 26R resembled the opposition to the original 9-Foot Channel Project in the 1930s, and hinged upon the unfair

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[26]Ibid., pp. 150-152; Colonel Thorwald R. Peterson, "Replacement for Locks and Dam No. 26," The Military Engineer, 66 (September-October 1974):287; Carol Koch, "Old 26 -- An Economic Bottleneck," Soybean Digest, 37 (December 1976):6.

competition that a government-owned river improvement represented for the industry.[27]

The Corps of Engineers issued a Draft Supplemental Environmental Impact Statement in June 1975. In February 1976 the Board of Engineers for Rivers and Harbors, at the request of the Chief of Engineers, recommended construction of a new dam and lock. This recommendation was forwarded to Congress in July 1976, and signed into law by President Jimmy Carter in October 1978.[28] Construction of Lock and Dam No. 26R began in 1980. Work on the project, estimated to cost approximately $900 million, is continuing. At the close of 1988 the first phase of the dam had been completed and work was nearing completion on the 1,200-foot long lock.

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[27]Dobney, River Engineers, p. 152; Merritt, The Corps, pp. 67-68.

[28]Colonel Leon E. McKinney, William R. Sutton, and Jean-Yves Perez, "Locks and Dam No. 26: Rehabilitation Versus Replacement," The Military Engineer, 72 (March-April 1980):110-111.

TECHNOLOGICAL HISTORY

The Upper Mississippi River 9-Foot Channel Project, as originally conceived and constructed, created a series of slackwater navigation pools, an "aquatic staircase" comprised of twenty-six locks and dams, and their associated pools, that extended from St. Paul, Minnesota south to Alton, Illinois. The subsequent construction of Mississippi River Lock No. 27 and the low water dam at Chain of Rocks Reach extended the channel to St. Louis, Missouri. The pools provide a uniform 9-foot channel depth along the entire Upper Mississippi. River traffic utilizes the locks to move between the individual pools, while the movable dams accurately regulate the pool heights to maintain the channel and protect against widespread flooding.[29]

The individual lock and dam installations designed and constructed during the 1930s are all comprised of the same basic components. The lock includes a main navigation lock, measuring 110 feet wide by 600 feet long, through which traffic passes between the navigation pools, and the upper miter gates of an

[29]River traffic, largely barges strung together to form tows, utilize the locks to pass between pools. A tow enters a lock, the gates are closed behind it, and the lock is either flooded or drained to raise or lower the tow to the height of the adjacent pool. The opposite set of gates are then opened and the tow proceeds across the pool to the next lock, where the operation is repeated.

auxiliary lock, originally designed to pass traffic during extended closures of the main lock or to permit future expansion of the installation. The dam consists of a movable non-navigable dam, abutting the river side of the locks, that generally includes a combination of roller and Tainter gates. The movable dam, and a series of submersible and non-submersible earth dikes that connect the movable portion of the dam to the far shore, form the navigation pool. The lock and dam structures are generally pile-founded, the reinforced concrete foundations resting on pilings driven into the riverbed sand.

Each installation in the St. Louis District exhibits minor variations in the general configuration described above. Lock No. 24 is not pile-founded, but rests on bedrock. Dam No. 24 includes no roller gates, but consists solely of Tainter gates. The auxiliary lock at Lock No. 26 was completed as part of the original project, not simply stubbed in for possible future construction. Additionally, the details of the design differ from installation to installation, because of both the specific requirements associated with each construction site and the rapid and continual evolution of the requisite technologies throughout the course of the project.

Lock No. 27, constructed between 1947 and 1953, consists of the same basic elements as those installations constructed during the 1930s; however, the details of its design and construction differ significantly.[30] Likewise, Lock and Dam No. 26R, includes all the basic elements included in the previous installations. The most evident difference between Lock and Dam No. 26R and its predecessors, including Lock and Dam No. 27, is the enormous scale of the new project. The Tainter gates, vertical lift gates, and other components at the new installation dwarf those previously constructed.

Perhaps the most significant technological advance incorporated into the Lock and Dam No. 26R project, although not readily apparent at the construction site, is the comprehensive testing program implemented at all phases of the project. A host of monitors, sensors, lasers, and computers have measured and analyzed concrete creep and shrinkage, pile compression, tension, and lateral resistance, and virtually every other aspect of the project's design and construction. The results of this testing have led the Corps of Engineers to refine the design and construction process for many elements of the

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[30]The principal differences are Lock No. 27's location on the man-made Chain of Rocks Canal, rather than on the Mississippi, and the use of vertical lift gates, instead of miter gates, at the upper end of the lock chambers.

project, saving thousands of dollars in material and labor through improved efficiency.[31]

Development of a design for the navigation locks proved a relatively simple task for the Corps of Engineers. River stages on the Upper Mississippi rarely provided the opportunity for open river navigation, necessitating the use of locks throughout the navigation season. The Corps designers decided to utilize locks "patterned to a large extent after those on the Ohio River."[32] This lock design, which reached its mature form ca. 1913, had already been proven reliable, durable, and efficient. Accordingly, the Corps of Engineers saw no need to develop a new design for the Upper Mississippi River Project.

The basic design employed monolithic reinforced concrete walls to enclose a lock chamber measuring 110 feet wide by 600 feet long, sufficient to accommodate the largest tows then in use on the inland waterways. Culverts in the lock walls, controlled by

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[31]Allen Soast, "Navigation Locks Design Becomes Research Project," Engineering News Record, 219 (August 6, 1987):38-40. Examples of the refinements and improvements yielded by the testing program include the decision to construct the lock chamber as a U-shaped megastructure, rather than as isolated gravity side walls with a base slab, and the determination that steel sheet piling used in the construction of the cofferdams did not need to be driven as deeply into the riverbed as in previous practice to provide adequate support.

[32]House Doc. 137 (1932), p. 98.

electrically operated valves, permitted water to enter or leave the lock chamber through a series of ports located near the floor of the chamber. Vertically-framed miter gates, pivoting upon cast steel pintles and supported, when closed, upon steel beams embedded in the reinforced concrete gate sills, also operated electrically. All of the locks constructed on the Upper Mississippi River during the 1930s in the St. Louis District conform to this basic design. Corps designers did, however, introduce a number of refinements and innovations to this basic design, largely associated with the system of culverts used to flood and drain the lock chamber, during the course of the project.[33]

The evaluative process that led to development of the basic design of the dams constructed for the Upper Mississippi River Project during the 1930s proved significantly more complex than that for the locks. The hydrological characteristics of the Upper Mississippi River and the Ohio River are quite different, precluding use of a dam modeled after those already used on the Ohio River.

At the earliest design stages the Corps of Engineers determined that the dams employed on the Upper Mississippi River Project

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[33] Ibid.

could not raise river heights more than one foot above prevailing flood stages. An increase of river heights above this limit would cause widespread flooding of towns, villages, railroads, and rich farmland located within the wide Mississippi flood plain. Accordingly, Corps designers determined that the project's dams must be movable, capable of being raised or lowered to permit the unrestricted flow of the river.[34]

Prior to the onset of the Upper Mississippi River 9-Foot Channel Project the majority of the movable dams constructed in the United States incorporated navigation passes that permitted river traffic to pass directly over the dam, bypassing the navigation lock, during sustained periods of high water. The navigation dams on the Ohio River consisted of a series of wickets supported and hinged upon a low foundation. Skilled operators working aboard a derrick boat raised or lowered the wickets as required. When the river flow permitted open river navigation, the wickets were lowered onto the dam sill and

[34] House Doc. 137 (1932), pp. 20-21; "Roller-Gate Dams for Kanawha River," Engineering News-Record, 111 (September 21, 1933): 338; W. H. McAlpine, "Roller Gates in Navigation Dams," The Military Engineer, 26 (November-December 1934): 419; Gross and McCormick, "The Upper Mississippi," p. 314; Hill, "Developing the Upper Mississippi," p. 1354; "Canalizing the Mississippi for 9-Ft. Navigation," Engineering News-Record, 112 (March 8, 1934): 323; S. G. Roberts, "Canalization of the Upper Mississippi River," Scientific American, 152 (February 1935): 72-73; E. L. Daley, "Canalization of the Upper Mississippi," Civil Engineering, 6 (February 1936):105.

traffic passed directly over the dam. During periods of low water the wickets were raised to create a pool, and traffic passed through the navigation lock located at one end of the dam.[35]

The conditions that prevailed along the Ohio River, combined with the limitations of available engineering and construction technologies at the time these structures were built, virtually required the use of navigable wicket dams, despite their apparent technical and operational shortcomings. Dams of this type cannot provide accurate and close regulation of pool heights, since the wickets are either fully raised or fully lowered, and their dependance upon skilled operators working in hazardous conditions aboard derrick boats makes them dangerous and expensive to operate. Additionally, repairs to the dam sill are difficult to undertake and may require an interruption in navigation.

The Ohio experiences extreme river stages of as much as sixty-nine feet, necessitating dams capable of passing large amounts of water while only minimally obstructing the stream's flow. In the last quarter of the nineteenth century, when the Ohio River

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[35]"Roller-Gate Dams," pp. 337-338; McAlpine, "Roller Gates," p. 419; Malcolm Elliott, "The Upper Mississippi River Project with a Discussion of the Movable Gates in the Dams," Paper presented at Western Society of Engineers, Chicago, 1937), p. 4.

dams were erected, available building technologies did not permit construction of gated dams with tall, widely spaced piers, as were required to meet these requirements. The Ohio's hydrological characteristics and the limitations imposed by contemporary engineering and construction practices, thus compelled designers to accept the use of wicket dams, which when lowered to their sills permitted almost free passage of the river. However, these high river stages also enabled designers to incorporate navigation passes in the dams, since high stages last long enough to permit extended periods of open river navigation.[36]

Environmental conditions on the Upper Mississippi offered a very different set of problems and opportunities to Corps of Engineers designers. A "stable and well behaved stream," the Upper Mississippi experienced flood stages of approximately twenty-one feet, nearly fifty feet less than on the Ohio. Open river stages in excess of four feet, sufficient to provide a 9-foot depth in the existing channel, occurred only briefly during the navigation season, compelling the use of navigation locks at all times. The combination of low river stages and the need for lockage facilities throughout the navigation season permitted

[36] Ibid., p. 4; "Roller-Gate Dams," pp. 337-338; McAlpine, "Roller Gates," p. 419; Gross and McCormick, "The Upper Mississippi River," pp. 313-314.

Corps designers to consider the use of non-navigable dams that partially obstructed the river flow.[37]

Non-navigable movable dams offered a number of technical and operational advantages over the navigable dams constructed by the Corps of Engineers on the Ohio River. A non-navigable dam consists of a series of reinforced concrete piers, supported on concrete foundations, with movable gates that close the openings between the piers. The individual gates are operated from a service bridge that extends the length of the dam across the tops of the piers and can be set at any desired opening, permitting accurate regulation of pool heights. The operation of the gates from atop the service bridge, rather than from aboard a derrick boat, made for safer and more dependable operations. The individual gate bays may be easily closed off with bulkheads and unwatered for repairs. Additionally, non-navigable dams tended to reduce hydraulic jump and downstream scour, two conditions that undermine dam structures.[38] This

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[37]Gross and McCormick, "The Upper Mississippi River," p. 311; House Doc. 137 (1932), p. 20.

[38]Hydraulic jump is a phenomenon associated with the tendency for water flowing over a structure to fall in a determinable curve. If the curve of the water falls well beyond the face of the structure a vacuum can form that literally sucks the concrete or other building material from the structure. Careful design and the provision of baffles and settling basins serve to reduce and control hydraulic jump. Scour is a condition that results from water passing over a structure and roiling along the riverbed below the structure. The force of the water can excavate large holes in the riverbed, ultimately undermining the structure. The downstream

proved an important considerations on the Upper Mississippi, where the majority of the structures are supported on pilings driven into the riverbed sand.[39]

Several types of gates could be incorporated into the design of a non-navigable dam. Environmental conditions on the Upper Mississippi greatly influenced the Corps' decision regarding the optimal type of gate to install in the dams. Heavy winter ice conditions on the Upper Mississippi required gates that operated reliably in subfreezing temperatures and that could span spillway openings up to one hundred feet wide, the spillway size Corps designers estimated was necessary to pass accumulated ice safely downstream in the spring. At the onset of the project, only roller gates met these design and operating criteria. Accordingly, Lieutenant Colonel George R. Spaulding's Upper Mississippi Valley Division design team, headed by William H. McAlpine, developed a basic dam configuration consisting of three or four roller gate sections, which passed ice and obstructions safely downstream, and a varying number of smaller sections, fitted with Tainter gates, an alternative gate type

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apron, derrick stone protection, and baffles, reduce the force of the water and permit it to pass downstream safely.

[39]"Roller-Gate Dams," p. 338; Daley, "Canalization," p. 105; Elliott, "The Upper Mississippi," pp. 4-5.

that cost less money to fabricate and erect and proved simpler to operate.[40]

The decision to utilize roller gates as a principal component of the Upper Mississippi River Project dams represented a massive commitment on the part of the Corps of Engineers to a largely unfamiliar, and foreign, technology. Developed in Germany ca. 1902 by Dr. Max Karstanjen, Director of the Maschinenfabrik Augsburg-Nurnberg (MAN), roller gates could be fabricated to close large spillway openings, permitting maximum flow of floodwaters and reducing the number of piers obstructing the stream. Roller gates were fairly widely used in northern Europe, particularly in Germany and Scandinavia, and their massive construction and successful operation under severe conditions convinced the Corps of Engineers of their practicality for the Upper Mississippi River.[41]

The earliest roller gates were simply internally braced hollow steel cylinders or drums that, when lowered, rested directly upon the dam sill. An early improvement to the basic design consisted of the attachment of a curved steel apron to the lower

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[40]House Doc. 137 (1932), pp. 21-22, 97; "Roller-Gate Dams," p. 338; McAlpine, "Roller Gates," pp. 422-423; Elliott, "The Upper Mississippi," p. 6; Gross and McCormick, "The Upper Mississippi," p. 314.

[41]McAlpine, "Roller Gates," p. 420; "Roller-Gate Dams," p. 338.

side of the drum, which reduced the required drum diameter and permitted use of a timber or rubber seal to form a more reliable and waterproof seal between the gate and the dam sill. The solid ends of the drum were fitted with sprocket teeth that engaged an inclined rack set into the pier face. A multiple side-bar chain, similar to an enormous bicycle chain, raised or lowered the gate. The chain wrapped around the drum and connected to both the gate and a hoisting engine housed atop the pier. When the engine hauled in the chain the gate moved slowly up the inclined racks. Only one end of the drum was driven, the other end merely rode up the racks.[42]

The first roller gates in the United States were used on flood control and irrigation projects. In 1914 the Washington Water Power Company used three roller gates for spillway crest control at a dam located on Long Lake near Spokane, Washington. A second installation, at a United States Reclamation Service dam near Boise, Idaho, employed a single small roller gate, measuring 8 feet tall by 30 feet wide.[43]

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[42]McAlpine, "Roller Gates," p. 420-421; "Roller-Gate Dams," pp. 338, 340-342.

[43]F. Teichman, "Large Roller-Crest Dam, Grand Valley Project, Colorado," <u>Engineering News</u>, 76 (July 16, 1916):4.

In 1916 the United States Reclamation Service utilized seven roller gates, measuring up to fifteen feet tall and seventy feet wide, in a new irrigation dam located near Palisade, Colorado. Contemporary engineering journals published several articles on the design and operation of this dam, which the Reclamation Service believed to be the third use of the roller gate in the United States. These articles served to disseminate information on roller gates to the American engineering community.[44]

Construction of the Grand River Dam provided the Reclamation Service with considerable experience in the fabrication and erection of roller gates, particularly since the outbreak of World War I in Europe prohibited the German patent holder, M.A.N., from completing their contract to design and fabricate the gates. A designing engineer for the Reclamation Service, F. Teichman, hurriedly reworked the German plans to conform to American practice, and in late 1914 the Riter-Conley Manufacturing Company of Pittsburgh, Pennsylvania began fabricating the gates for a low-bid contract price of just under $15,000. Reclamation Service crews erected the gates.[45]

[44]Teichman, "Large Roller-Crest," pp. 1-4; "Building the Rolling-Crest Dam Across Grand River," Engineering News, 76 (July 13, 1916):60-64; S. O. Harper, "Operation of Grand River Roller Dam Proves Satisfactory," Engineering News-Record, 80 (June 27, 1918):1225-1226.

[45]"Building the Rolling-Crest Dam," p. 61.

Subsequent to the Grand River project a small number of additional roller gate dams were erected in the United States.[46]

The Corps of Engineers determined to employ roller gates on the Upper Mississippi River 9-Foot Channel Project dams sometime in 1930. The interim report of the special board of engineers appointed to survey the Upper Mississippi for the purpose of securing a 9-foot channel, issued in December 1929, made no specific recommendation regarding the type of dam or the type of gates to be used in the project, but mentioned wicket, "taintor," and roller dams as possible design solutions.[47] A year later, in December 1930, the special board of engineers' final report specifically recommended dams consisting of a combination of roller and Tainter gates.[48]

The first Corps of Engineers dam to employ roller gates was Mississippi River Dam No. 15, located at Rock Island, Illinois. Almost simultaneously with this work the Corps designed roller-gated dams for two locations on the Kanawha River, a West Virginia tributary of the Ohio. The two West Virginia dams used

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[46]"New Power Plant Replaces Old Waterwheels," Engineering News-Record, 90 (December 8, 1927):908-911; C. R. Martin, "New Design Cuts Cost of Roller Gates," Engineering News-Record, 122 (May 25, 1939): 67.

[47]House Doc. 290 (1930), p. 40.

[48]House Doc. 137 (1932), p. 21.

gates that conformed to the German patents held by the Krupp company, while Dam No. 15's gates conformed to designs patented by M.A.N. The United States rights to these patents were held, respectively by the Dravo Contracting Company of Pittsburgh, Pennsylvania, who fabricated and erected the West Virginia gates, and the S. Morgan Smith Company of York, Pennsylvania, who performed the same work at the Dam No. 15.[49]

Each of these two early Corps of Engineers roller gate dams innovated and improved upon current roller gate design. The innovations in design and construction pioneered on the Kanawha River and at Rock Island, Illinois paved the way for a host of improvements in gate design that took place throughout the course of work upon the Upper Mississippi River 9-Foot Channel Project.

At the Kanawha River dams, Corps designers specified that one of the five gates be fully submergible to facilitate the passing of ice and debris. Dravo Contracting, the gate contractor, proposed instead to fabricate one gate with a movable flap hinged to the top of the drum. This flap could be lowered onto the face of the drum, providing a five-foot overflow atop the

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[49]"Roller-Gate Dams," pp. 338-340; "Roller-Gate Dam Erection at Rock Island, Illinois," Engineering News-Record, 112 (March 29, 1934):410-414.

gate.[50] Although this innovation was not widely used in subsequent Corps of Engineers roller gate dams, it pointed the way towards the use of submergible gates, the most significant innovation in roller gate design to emerge from the 9-Foot Channel Project.

Upon its completion in March 1934, Dam No. 15 on the Mississippi River at Rock Island, Illinois constituted the largest roller gate installation constructed in the world. Individual gates had been built in Europe that were both larger and longer, but never had a single dam incorporated so many gates, of such an aggregate length.[51] The construction methods and techniques developed for this project served as models for the remainder of the Upper Mississippi 9-Foot Channel Project.

Although the 1930 decision to incorporate roller gates into the design of the Upper Mississippi River Project dams represented a major technical advance in its own right, through the commitment to a relatively unfamiliar foreign technology, Corps designers refined and improved the design and operational characteristics of roller gates throughout the course of the Upper Mississippi River Project. These innovations and

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[50]"Roller-Gate Dams," pp. 340-341.

[51]"Roller-Gate Dam Erection," p. 410.

improvements resulted in the development of a decidedly American style submergible roller gate. The impetus behind this innovation originated in the desire to pass ice down river without drawing down the level of the navigation pools.

In non-submergible roller gates the seal at the lower end of the gate apron rested directly against the dam sill. Submergible gates incorporated a curved sill that permitted the gate apron to pass over the sill plate to a gate stop, lowering the gate three to five feet below the level of the upper pool. The design of both the pier rack casting, on which the gate drum rode, and the gate end shields were modified on submergible gates. The lower portion of the rack casting curved sharply downstream, permitting the gate to drop almost vertically as it passed beyond the dam sill to the gate stop. Large end shields covered the pier recesses when the gate was submerged, protecting the rack castings from drift and ice. Careful attention to the shape of the shields enabled them to fall directly behind the dam sill, eliminating the need to provide slots in the sill through which the shields passed, as was common practice in Europe. Eliminating these slots removed a possible collecting point for ice, silt, and drift.[52]

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[52]Daley, "Canalization of the Upper Mississippi," p. 106; McAlpine, "Roller Gates," p. 422.

Two of the three dams constructed in the St. Louis District during the 1930s incorporate roller gates, and all of these gates are fully submergible. Dam No. 26, designed in December 1934, includes three roller gates, each measuring twenty-five feet tall and eighty feet long. The three roller gates at Dam No. 25, designed in January 1937, each measure twenty-five feet by one hundred feet. The basic design of these gates corresponds to the description above.[53]

While roller gates embodied the newest form of movable dam technology and attracted the greatest attention in the engineering press, Tainter gates constituted the majority of the gates constructed by the Corps of Engineers on the Upper Mississippi. The technological innovations achieved in the design and construction of Tainter gates during the course of the 9-Foot Channel Project proved far more significant than the adoption of roller gates and their subsequent innovation.

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[53]St. Louis District, Corps of Engineers, "Final Report -- Lock and Dam No. 26, Mississippi River, Alton, Ill., Part II -- Dam/Auxiliary Lock," p. 1. Typescript draft on file at St. Louis District Office. Hereafter cited as "Final Report -- Lock and Dam No. 26, Part II;" Mississippi River Lock & Dam No. 26, Dam -- General Plan, Drawing No. M-L 26 40/1 (December 1934); St. Louis District, Corps of Engineers, "Lock and Dam No. 25, Mississippi River, Cap Au Gris, Missouri, Specifications for Construction of Dam" (St. Louis: Corps of Engineers, 1937), p. 2. Copy on file at site, hereafter cited as "Lock and Dam No. 25, Dam Specifications."

Tainter gates are of American origin, with early installations dating to 1827. Jeremiah Tainter, who gave the gate his name, patented the basic design in 1886.[54] In its simplest form a Tainter gate consists of a curved shell, essentially a section of a cylinder, supported by radial arm frames that rotate about a fixed horizontal axis anchored in the masonry of the dam piers. The cylindrical section of the gate forms the damming surface. The gate is raised or lowered, regulating the flow of water over the dam spillway, by means of a cable or chain attached to the lower side of the gate shield and driven by machinery located above the gate on the dam's service bridge. The shape of the gate is such that the water pressure behind the gate has little effect and the hoist machinery merely has to overcome the deadweight of the gate.[55]

Tainter gates are economical and simple to fabricate, erect, and operate. However, at the onset of the 9-Foot Channel Project they could only be fabricated to a maximum width of approximately thirty feet and they had an uncertain history of

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[54]Rathbun Associates, "HAER Documentation," pp. 68-71; O'Brien, "Upper Mississippi River," p. 29; Elliott, "The Upper Mississippi River," p. 9.

[55]Elliott, "The Upper Mississippi," p. 8; William P. Creager, Joel D. Justin, and Julian Hinds, Engineering for Dams, 3 vols. (New York: John Wiley & Sons Inc., 1945), 3:893; Armin Schoklitsch, Hydraulic Structures: A Text and Handbook (New York: American Society of Mechanical Engineers, 1937), pp. 648-657.

operation under severe ice conditions. Given these size and operational limitations, and given the Corps' requirements for a 100-foot gate that operated reliably under adverse conditions, Corps designers determined to provide the main channel at each dam with three or four roller gates, to assure the efficient and safe discharge of ice downriver, and to complete the movable portion of each dam with a series of smaller, simpler, and less costly Tainter gates.[56]

Throughout the course of the Upper Mississippi River Project the Corps of Engineers designers refined and improved the various component elements of the lock and dam installations, although they worked within the confines of a basic design configuration developed at the onset of the Project. The elements of this basic configuration, a movable, non-navigable dam, generally containing a combination of roller and Tainter gates, and a 110-foot by 600-foot navigation lock, are identifiable at virtually all of the installations constructed during the 1930s.

The Corps of Engineers considered the three lock and dam installations constructed in the St. Louis District during the 1930s low priority, or Group D, structures because dredging alone could maintain a 9-foot channel in this portion of the

[56]Daley, "Canalization," p. 106; Elliott, "The Upper Mississippi," p. 9.

river.[57] As a result, the design and construction of these installations lagged behind that of installations on the upper reaches of the river, where a 9-foot channel could only be attained by canalization. Accordingly, many of the technical innovations discussed in the two previous studies of the 9-Foot Channel Project had attained the position of common or standard practice at the time that work began on the structures in the St. Louis District.[58]

Nevertheless, the St. Louis District affords an excellent opportunity to study the technical evolution of this major civil engineering and river navigation improvement project. Construction in the District spanned the period from 1934 to 1940. The twin locks at Alton, Illinois (No. 26), designed by the Upper Mississippi Valley Division prior to the assignment of design responsibilities to individual Districts at the close of 1933, reflect the level of technological knowledge immediately following the earliest phases of the project. Lock and Dam No. 24, completed in 1940 as the final installation in the 9-Foot Channel Project, clearly reveals the technical advances made during the seven years since the design of Lock No. 26.

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[57]House Doc. (1932), p. 11.

[58]O'Brien, "Upper Mississippi River," pp. 24-40; Rathbun Associates, "HAER Documentation," pp. 49-89.

Additionally, the St. Louis District includes two installations erected after the completion of the initial 9-Foot Channel Project. Lock No. 27, and the associated Chain of Rocks Canal, were built between 1947 and 1953, and represent a decidedly different scale and approach to construction from the earlier installations. Dam No. 27, also known as the Chain of Rocks low water dam, was erected in the early 1960s and is indicative of efforts to improve upon the initial navigation system. Finally, Lock and Dam No. 26R, presently under construction, brings the 9-Foot Channel Project into the present. This installation, designed to replace the original Lock and Dam No. 26, incorporates the most modern design lessons and philosophies, and represents the culmination, for the moment, of Mississippi River navigation improvement technology.

The major technological innovations associated with the 9-Foot Channel Project in the St. Louis District relate to gate design and fabrication, the testing and analysis of pile foundations, and, after 1945, the continued enlargement, refinement, and improvement of these innovations. The principal innovations associated with the major components of the lock and dam system are discussed in detail below. While innovations and improvements in each element are discussed separately, it must be stressed that these installations functioned as a system, and that improvement in one element of the system frequently permitted, facilitated, or compelled improvement in another element.

The rapid evolution in Tainter gate design represents the most significant technological development associated with the 9-Foot Channel Project in the St. Louis District, and is arguably the most important technical advance to emerge from the entire project. At the onset of the project the Corps designers considered Tainter gates too small and too unreliable, in terms of their operation under adverse conditions, to be used in the principal spillway sections of the dams. Roller gates, more expensive to fabricate and more complex in their method of operation, occupied these locations. By the conclusion of the project, as exemplified in the construction of Lock and Dam No. 24, Tainter gates could be built to lengths of eighty feet, eliminating the need for the more expensive and complicated roller gates.

Tainter gate design evolved with astounding rapidity. The speed of innovation was noted by a Corps officer who commented that "the first dam of a series may be partially out-of-fashion by the time the last one is built."[59] This rapid evolution in gate

[59]Elliott, "The Upper Mississippi," p. 3.

design is well represented in the three St. Louis District dams constructed during the 1930s.

Dam No. 26, designed in 1934 and constructed between 1935 and 1938 has thirty forty-foot wide submergible Tainter gates. The gate may be lowered three feet past the top of the dam sill, which is curved, in section, to permit this movement, allowing water to flow across the top of the gate. The downstream face of each gate is fitted with a streamlined spillway that directs water passing over the gate out and away from the gate's exposed steel frame. Corps designers developed submergible gates to improve operational conditions. The engineers determined that it was necessary to raise the dam gates entirely clear of the water to permit the heavy ice on the Upper Mississippi to pass freely downstream. This practice drew down, or lowered, the elevation of the upper pool, adversely effecting the natural habitat and creating the possibility of scour below the dam apron and stilling basin. Submergible gates permitted ice and other obstructions to pass freely, while retaining a significant percentage of their damming capacity.[60]

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[60]Mississippi River Lock & Dam No. 26, Dam -- Tainter Gates -- General Drawing, Drawing No. M-L 26 48/1 (August 1934); Daley, "Canalization," p. 106.

Dam No. 25, designed in 1936 and constructed in 1937 and 1938 includes fourteen sixty-foot wide submergible Tainter gates. These gates represented a marked advance over those installed at Dam No. 26. The gates were fully submergible to a depth of nearly eight feet, more than twice that attained at Dam No. 26. Additionally, the streamlined spillway that characterized the Dam No. 26 gates was replaced by a riveted steel shell that entirely covered the gate's steel framework, protecting it from ice damage and providing a smooth unobstructed surface for the water that passed over the gate in its submerged position.[61]

At Dam No. 24, designed in December 1937 and constructed, as the last Upper Mississippi River Project dam, in 1938 and 1939, Tainter gate design reached a new level of sophistication. The 1,340-foot long movable portion of the dam consisted solely of fifteen eighty-foot wide Tainter gates. The large size of these gates, and the relatively ice free conditions that characterize this stretch of the Mississippi, convinced Corps designers to entirely eliminate roller gates from this dam.

The Tainter gates at Dam No. 24 are fully submergible and are elliptical in section. The elliptical design permits the shell

[61]Mississippi River Lock & Dam No. 25, Dam -- General Arrangement of Tainter Gate Dam, Drawing No. M-L 25 40/3 (January 1937); Daley, "Canalization of the Upper Mississippi," p. 106.

of the gate to act as a beam between the end supports, eliminating the need for extensive internal bracing and framework, reducing both the quantity of steel required to fabricate the gate and its operational weight. An additional reduction in weight, as well as an improvement in corrosion resistance, resulted from the use of high tensile, phosphorous chromium steel for most movable portions of the gates, including the shell, its internal supports, the trunnion arms, and the end projections that provided the seal between the gate and the pier. At the time of their construction the Corps of Engineers believed the Dam No. 24 gates to be the largest Tainter gates ever constructed.[62]

The eighty-foot, submergible, elliptical Tainter gates at Dam No. 24 represent a vast improvement over the forty-foot gates designed only four years previously for Dam No. 26. The scope of the improvement is clearly indicated by the elimination of the more costly and complex roller gates from the latter dam. Within the space of four years Corps designers had improved the design of Tainter gates so dramatically that roller gates, the principal engineering feature discussed in early technical

[62]Mississippi River Lock & Dam No. 24, Dam -- General Arrangement -- Tainter Gate, Drawing No. M-L 24 40/2 (December 1937); Elliott, "The Upper Mississippi," p. 14; Gross and McCormick, "The Upper Mississippi," p. 314.

articles related to the 9-Foot Channel Project, were entirely superceded by a cheaper, simpler, and more reliable gate type.

The Tainter gates that will comprise Dam No. 26R, the replacement for the aging Dam No. 26, embody present Tainter gate technology. The principal difference between these gates and those constructed in the 1930s is their enormous size. Each of the nine non-submergible, open-frame gates measures 110 feet across and 42 feet high. They are nearly three times the width of the gates at the original Dam No. 26 and nearly forty percent larger than the eighty-foot gates erected at Dam No. 24, the largest Tainter gates erected as part of the initial Upper Mississippi River Project.[63]

The Dam No. 26R Tainter gates differ little from their predecessors except in size. They are constructed and operated in essentially the same fashion as the earlier gates. The development, in the late 1940s, of vertical lift gates for navigation locks, as constructed at Lock No. 27, permitted ice to be efficiently passed downstream through the lock chamber and eliminated the need for submergible Tainter gates in the dam structure. Accordingly, the design for Lock and Dam No. 26R

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[63]Thorwald R. Peterson, "Replacement for Locks and Dam No. 26," The Military Engineer, 66 (September-October 1974): 287.

incorporated vertical lift gates at the upper end of the lock chamber and non-submergible open-frame Tainter gates in the dam.

The St. Louis District initiated relatively little improvement or innovation in the methods used to raise and lower roller and Tainter gates. The six roller gates in the District were raised and lowered by individual, electrically-operated stationary hoists located in machinery houses atop the dam piers. The hoist machinery was placed atop the piers prior to construction of the reinforced concrete machinery houses.

The District's Tainter gates were all designed to be hoisted by individual electric motors, coupled to line shafts, located beneath the service bridge spans. Early installations in other Districts employed a hoist car operating along the service bridge to raise and lower the Tainter gates, but the development, by Corps engineers, of the motor and line shaft system, although more expensive to construct and install, permitted rapid simultaneous operation of several gates and required fewer operators. After September 1934 all new dam construction on the Upper Mississippi, including those structures located in the St. Louis District, utilized motors and line shafts for hoisting Tainter gates.[64]

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[64]Rathbun Associates, "HAER Documentation," p. 71; Elliott, "The Upper Mississippi," p. 18; Daley, "Canalization," p. 106;

All of the dams constructed in the St. Louis District, including the new Dam No. 26R, are pile founded structures. The concrete foundations of the dam are supported on a multitude of pilings driven into the deep layers of riverbed sand. This form of construction gains significant structural stability from the foundation sands that surround the pilings. Loss of this sand through erosion, frequently the result of scour, can significantly reduce the structure's stability. Corps engineers in the 1930s devoted a significant amount of time to the design of the dam sill and apron to assure that water passing over the spillway did not carry off foundation sands and undermine the structure.

Below the movable gates each dam incorporated an elaborate stilling basin that served to control the water's hydraulic jump and dissipate its energy so that it flowed placidly downstream. The basic design of the various elements that comprised the stilling basin, which, like the remainder of the dam structure rested atop pile foundations driven deep into the river bottom, evolved prior to the design of the St. Louis District structures. Only minor refinements to this design, and the provision of additional protection in the form of timber and riprap mattresses and derrick stone, characterized the District's efforts in this area.[65]

The first element of the stilling basin consisted of a reinforced concrete apron located directly below the dam sills and extending thirty-six to fifty-two feet downstream. The length of the apron varied according to gate type and the specific hydrological conditions of the dam site. A series of concrete baffles, positioned at the upstream edge and midpoint of the apron, helped dissipate the energy of the water passing over the spillway. Timber mattresses laden with up to four feet nine inches of derrick stone butted against the edge of the apron and extended a further forty-eight feet downstream, protecting the pile foundations from the effects of scour. Additional timber and stone mattresses protected the upstream face of the dam. Steel sheet pile cutoff walls were driven above and below the dam to prevent the passage of water directly beneath the structure.[66]

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[65]Riprap consists of broken stone thrown together irregularly, generally on a soft surface or in water. Derrick stones are large stone blocks that must be placed by derricks because of their weight.

[66]Mississippi River Lock & Dam No. 26, Dam -- General Plan, Drawing No. M-L 26 40/1 (December 1934); Thomas J. Mudd, "Locks and Dam No. 26, Mississippi River -- Alton, Illinois" (St. Louis: St. Louis District, Corps of Engineers, 1975), p. 3; Mississippi River Lock & Dam No. 25, Dam -- General Plan, Drawing No. M-L 25 40/1 (January 1937); Mississippi River Lock & Dam No. 24, Dam -- General Plan, Drawing No. M-L 24 40/1 (December 1937).

This elaborate and extensive system of protection has failed to prevent the development of deep scour holes approximately 200 feet downstream from Dam No. 26. The largest of these holes is deeper than the pilings that support the dam. Corps engineers are concerned that this scour hole could creep upriver towards the dam, ultimately undermining and threatening the structure.[67]

Technical innovation in the design of the Upper Mississippi River Project navigation locks proved much more incremental than that associated with the dams. The Corps had perfected the basic lock design employed in the project on the Ohio River ca. 1913, and innovation was accordingly limited to relatively minor refinements of the existing design. Nevertheless, important improvements in lock design, particularly in regards to the system used to fill and drain the lock chambers and the use of vertical lift gates, resulted from the 9-Foot Channel Project. The most significant of these developments occurred after 1945 and are associated with the design and construction of Lock No. 27.

The most significant alteration to the original Ohio River lock design, utilized at all of the Upper Mississippi locks, involved

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[67]Mudd, "Locks and Dam No. 26," p. 14.

the plan of the culverts and ports used to flood and empty the chambers. The Ohio design utilized a series of small culverts passing directly through the lock's river wall above and below the dam, each individually controlled by a valve, to flood and empty the chamber. This complex system was eliminated on the Upper Mississippi locks in favor of large longitudinal culverts located in the base of the lock walls controlled by only four valves, which provided greater dependability and required less maintenance. Intake and discharge openings were located in the lock walls, respectively above the upper gates and below lower gates. A series of small ports branched off the main culverts and flooded or emptied the lock chamber.[68]

The use of Tainter valves to control the flow of water into and out of the lock chamber also represented a departure from Ohio River practice. In the special board of survey's final report, issued in December 1930, the design of the valves and operating machinery for the locks had yet to be determined. The report noted that three types of valves were being considered; Stoney roller valves similar to those used in the Panama Canal locks, butterfly valves, such as those used at the Emsworth and

[68]House Doc. 137 (1932), p. 98.

Dashields Dams on the Ohio River, and "Taintor gates," as used on the Welland Canal.[69]

The Tainter valves ultimately adopted by the Corps for use in the locks functioned in the same fashion as the larger Tainter gates incorporated into the dams. The valves were raised and lowered from above by electrically driven cable hoists. Seals on the sides and bottom of the valves enabled them to close off the culverts in the lowered position, preventing water from entering or leaving the lock chamber, as desired.

The Corps designers incorporated provisions for auxiliary locks into the majority of the Upper Mississippi sites. Only Lock and Dam No. 15, at Rock Island, Illinois, and Lock and Dam No. 26 at Alton, Illinois, were actually provided with auxiliary locks. At all other locations auxiliary locks were stubbed into place for possible future construction. These provisions consisted of portions of the river wall, machinery recesses, and the upper lock gates, which could be opened and used to pass traffic during periods when the dam was fully raised and the pool drawn down.[70]

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[69]Ibid.

[70]"Canalizing the Mississippi," p. 324; Daley, "Canalization," p. 105; Gross and McCormick, "The Upper Mississippi," p. 314.

The Corps designers made major advances in the analysis of the load bearing capacity of pile-founded structures during their design of the Upper Mississippi River locks and dams. In the St. Louis District Principal Engineer L. B. Feagin recognized that little field data existed for determining the resistance of piles subject to lateral loads, such as those resulting from backfill against the locks' land walls, or water pressure behind lock walls and dams. In the early phases of construction at Lock No. 26, which was designed to be founded upon 14,200 timber piles, with nearly 5,000 concrete piles placed in those areas that supported the greatest loads, Feagin resolved to determine the degree of safety afforded by this type of construction for Lock and Dam No. 26 and future projects within the District.

Feagin conducted a series of tests upon groups of vertical piles subjected to static and cyclical loadings. These test provided information on the behavior of the foundation piles under constant and changing loads, and led to a modification of the original lock design that introduced a series of pile-founded concrete struts extending, at floor level, between the land wall and the intermediate wall and between the intermediate wall and the river wall. These struts distributed the horizontal loads among the three locks walls, reducing the load on any single wall.[71]

Feagin conducted similar load tests upon groups of batter piles at Lock and Dam No. 25, and incorporated batter piles, as well as lock wall struts, into the design of this structure.[72] Lock No. 24, which rested upon a bedrock foundation, did not require the extra structural support afforded by the struts and they were not provided.[73]

At Lock and Dam No. 26 the movement experienced by both structures greatly exceeded the limits projected by Feagin's testing program, indicating that the installation's pile foundations were "grossly underdesigned." Nevertheless, Feagin's pile load tests represented a pioneering effort in the scientific analysis of pile-founded structures. Prior to Feagin's efforts engineers had little field data regarding the way large pile-founded structures behaved under loads. Feagin's testing program, though inadequate by modern standards, provided

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[71]Mudd, "Locks and Dam No. 26," p. 3.

[72]Batter or battered piles are driven at an angle rather than vertically. Battered pile foundations were used extensively at Lock and Dam No. 26R.

[73]Ibid.; St. Louis District, Corps of Engineers, "History and Cost Report Lock 24, Mississippi River" (St. Louis: Corps of Engineers, 1938), p. 1. Hereafter cited as "Final Report Lock No. 24."

a wealth of information on this vital subject and served as a standard form of analysis for many years.[74]

The most important advances in navigation lock design in the St. Louis District occurred after 1945, with the construction of Lock No. 27, located on the Chain of Rocks Canal at Granite City, Illinois. Constructed between 1947 and 1953, this twin lock installation included a main lock measuring 110 feet wide and 1,200 feet long, the longest navigation lock on the Mississippi River, and an adjacent auxiliary lock measuring 110 feet wide and 600 feet long.[75]

The locks conform to the basic configuration established in the 1930s. The lock walls, which are as much as ninety-two feet tall, are of monolithic reinforced concrete construction founded on bedrock. Longitudinal culverts in the base of the lock walls flood and empty the lock chambers through ports in the walls of the main lock and through diffusers placed in the floor of the auxiliary lock. Unlike the earlier installations, where the culvert intakes were located in the lock walls, the intake ports are placed in the lock floor immediately above the upper gates. The arrangement of the discharge ports also varies from earlier

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[74]Mudd, "Locks and Dam No. 26," pp. 3-4; "Final Report -- Lock and Dam No. 26, Part I," pp. 16, 32, 34.

[75]Smyser, "Chain of Rocks Project," p. 16.

practice. Instead of large ports placed in the lock walls below the lower gates, Lock No. 27 utilizes a complex discharge manifold that releases water through the floor of the lock structure below the lower gates. The manifold greatly reduces the turbulence associated with the water emptying from the lock chamber.[76]

The downstream lock gates are electrically-operated miter gates, balanced on steel pintles, similar to those at the locks constructed in the 1930s. The gates are extremely large, each leaf of the main lock gate measuring sixty-one feet across, seventy-two feet tall, and weighing 170 tons. The auxiliary lock gates are only forty-three feet tall and weigh 140 tons per leaf.[77]

The upper gates represent a distinct departure from previous practice on the Upper Mississippi. The placement of the lock on a canal necessitates that ice be passed through the lock chamber during the winter. Miter gates cannot be operated against an appreciable head of water, as required under these

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[76]Mississippi River Lock & Dam No. 27, Locks -- General Plan -- Elevations and Sections, Drawing No. M-L 27 20/2 (April 1947); Ibid., Intake and Upper Sill -- Main Lock, Drawing No. M-L 27 20/51 (April 1947); Ibid., Discharge Manifold -- Both Locks, Drawing No. M-L 27 20/54 (April 1947).

[77]Smyser, "Chain of Rocks Project," p. 17; "Biggest Lock on the Mississippi," Engineering News-Record, 145 (October 5, 1950): 30.

circumstances, so Corps engineers designed double-leaf vertical-lift gates for the upper gates. With the lock emptied and the lower miter gates fully opened, the downstream leaf of the lift gate may be lowered, much like a double-hung window, until it nests behind the upstream leaf. Ice may then pass freely through the lock chamber. The lift gates are raised and lowered by electrically-operated, counterweighted chain hoists. The thirty-foot tall, 450-ton gate leafs ride up and down the gate recesses on reaction rollers.[78]

The design of Lock No. 27 contains a number of other minor departures from earlier practice. Six separate Control Stations replaced the single Central Control Station used at the earlier installations. These Stations are located at both ends of the east and intermediate lock walls, the upper end of the west wall, and the mid-point of the intermediate wall. Emergency bulkheads, placed by stiffleg derricks, are provided to close off the upper gate bays of the locks for repairs. Unwatering pumps, located within the lock walls, are then used to completely empty the lock chambers.[79]

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[78]Ibid.; Mississippi River Lock & Dam No. 27, Locks -- Lift Gate Machinery -- General Arrangement, Drawing No. M-L 27 22/51 (April 1947).

[79]Mississippi River Lock & Dam No. 27, Locks -- Buildings -- Key Plan, Drawing No. M-L 27 70/0 (April 1947); Ibid., Unwatering & Drainage Equipment -- General Arrangement, Drawing No. M-L 27 36/1 (April 1947); Ibid., Lock Bulkhead Handling Equipment -- General Arrangement, Stiffleg Derrick, Hoist & Pickup, Drawing No.

At the close of 1988 the main lock at Lock and Dam No. 26R was nearing completion. The installation is comprised of the same basic elements as those installations constructed in the 1930s. The scale of the individual elements is dramatically larger, but the movable dam, gated navigation lock, and submergible dikes connecting the structure to shore are all readily identifiable. The construction process, entailing the use of cofferdams and progress in distinct stages, also closely resembles the construction of the original 9-Foot Channel Project installations in the 1930s.

Lock No. 26R is a U-shaped "megastructure" supported on steel H-piles, up to eighty-one feet long. The piles are not driven vertically into the river bed, but are battered at angles to form a web-like foundation. This design is a significant departure from the traditional lock design of independent, isolated gravity side walls with a base slab between them. It provides a more fully integrated structure that is less susceptible to movement over time and ultimately more cost efficient. The base slab of Lock No. 26R is twenty feet thick at each end, tapering to fifteen feet in the middle. The side

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M-L 27 35/1 (April 1947).

walls, forty feet thick at their bases, rise more than sixty feet above the base slab.[80]

An auxiliary lock, separated from the main lock by two dam Tainter gate bays, may be constructed as part of the final phase of this replacement project. The main lock measures 1,200 feet by 110 feet, the same dimensions as the main lock at Lock No. 27. As with Lock No. 27, the new structure is fitted with downstream miter gates and upstream vertical lift gates, although the latter have three leaves rather than the two at Lock No. 27.[81]

The Corps of Engineers conducted an extensive program of measurement, observation, and computer testing at Lock No. 26R. This work has resulted in the refinement of a host of details, including the design and construction of cofferdams, the mixing and distribution of concrete, and the placement of guidewalls.

Extensive analysis, facilitated by the use of computers, subjected each section of the structure to as many as thirty combinations of loads. The Corps of Engineers' Waterway Experiment Station at Vicksburg, Mississippi conducted research

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[80] Soast, "Navigation Lock," p. 38.

[81] Ibid.; Peterson, "Replacement," p. 287.

on concrete creep and shrinkage, projected over the life of the structure, and determined that these conditions may impose greater force and stress upon the structure than other loads. Newly developed tests, refinements and improvements to those developed by L. B. Feagin in the 1930s, subjected vertical and batter piles to tension, compression, and lateral loads. The time required to conduct these tests was reduced from forty-eight to eight hours. Perhaps the most widely applicable benefit to emerge from the testing program was the discovery that the steel sheet piling used to construct cofferdams did not have to be driven into the riverbed as was previously thought. Driving the piling to a shallower depth reduced costs and increased the amount of piling that could be reused upon the removal of the cofferdam.[82]

The construction of the guidewalls offers perhaps the most novel departure from traditional lock and dam construction techniques. Corps engineers determined to build the 1,500-foot upstream and 855-foot downstream guidewalls in the wet, rather than follow the usual method of erecting an expensive cofferdam and working in the dry. The Corps utilized a novel system to erect the downstream wall. A series of sheet pile cells were driven into

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[82]Soast, "Navigation Lock," pp. 38-40; "Barge Bottleneck Uncorked," Civil Engineering (January 1987); "Girder-Mounted Crane Cuts Guidewall Costs," Highway and Heavy Construction, 130 (January 1988): 52-55.

the river bottom. H-beam piles were then driven through the center of each cell to increase its stability. Tremied concrete, a form of concrete capable of being placed underwater, was then placed within each cell, providing a foundation for a series of precast concrete beams, each weighing 225 tons, that were stacked atop the cells by a massive heavy-lift cantilever crane riding on a runway girder.[83]

The lock and dam complexes are largely devoid of conventional architecture. The design and appearance of the dam piers and lock walls largely resulted from engineering, not architectural, decisions. None of the installations in the St. Louis District, originally considered of low priority by the Corps of Engineers, exhibit the "Type 1" architectural characteristics discovered at pre-1936 installations in the St. Paul District. Both Dam No. 26 and Dam No. 25 display the streamlined style of roller gate machinery housing identified as "Type 2."[84]

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[83] "Girder-Mounted Crane," pp. 52-55.

[84] "Type 1" installations, completed prior to 1936, are characterized by roller gate operating houses with hipped roofs and large windows with industrial steel sash. The operating houses at "Type 2" installations, completed after 1936, display a more stream-lined Art Moderne sense of styling, with flat roofs, slit windows, and no unnecessary use of materials. O'Brien, "Upper Mississippi River -- Locks and Dams 3 Through 10 -- Individual Significance and Inventories," p. 1.

The design of the gate piers is different at each of the dams in the St. Louis District and reflect a continual effort on the part of Corps engineers to eliminate superfluous material from the pier structure. This effort is clearly evident in the design of the Tainter gate piers at Dam No. 24 which, although they carry far heavier loads than at Dam Nos. 25 and 26, contain significantly less material.

The Central Control Stations represent the most significant architectural statement at each of the three original Upper Mississippi River Project installations in the St. Louis District. The Control Station at Lock and Dam No. 26 is unique, being placed on the river wall against the dam structure. The steel frame and brick and tile construction of this Control Station served as models for those at Lock and Dam Nos. 24 and 25, although the location and design details of these latter two Control Stations do not correspond to those at Lock and Dam No. 26.

The Central Control Stations at Lock and Dam Nos. 24 and 25 are identical. The steel-framed brick and tile buildings are located on the land wall at approximately the mid-point of the lock chamber. The buildings, designed by Upper Mississippi Valley Division Associate Engineer Marshall Gray, and constructed under separate contracts from the work on the lock, originally displayed a streamlined, moderne appearance with flat, precast concrete slab roofs, precast concrete ornamental trim, and industrial metal sash windows.[85] Alterations, completed in late 1988, have slightly enlarged the buildings, obscured the original brick exterior beneath stucco, and replaced original window sash.

The Control Stations at Lock No. 27, designed in 1947, correspond in many regards to the design precepts employed at Lock and Dam Nos. 24 and 25. The buildings are faced in buff brick, with precast concrete trim, and display a decidedly streamlined appearance.[86] Designs for the Control Station at

[85] St. Louis District, U.S. Corps of Engineers, "Lock & Dam No. 25, Mississippi River, Cap Au Gris, Missouri, Specifications for Construction of Central Control Station" (St. Louis: Corps of Engineers, 1938). Copy on file at site. Hereafter cited as Lock and Dam No. 25 -- Central Control Station Specifications; Mississippi River Lock & Dam No. 25, Central Control Station -- Elevations, Drawing No. M-L 25 70/1 (February 1938); Ibid., Floor Plans, Drawing No. M-L 25 70/2; Ibid., Sections, Drawing No. M-L 25 70/3; Mississippi River Lock & Dam No. 24, Central Control Station -- Elevations, Drawing No. M-L 24 70/1 (December 1937); Ibid., Floor Plans, Drawing No. M-L 24 70/2; Ibid., Sections, Drawing No. M-L 24 70/3.

[86] Mississippi River Lock & Dam No. 27, Locks -- Control House -- Upper East Wall -- Elevations, Drawing No. M-L 27 70/3 (April 1947); Ibid., Locks -- Control House & Crane Machinery House -- Upper West Wall -- Plans, Elevations, Sections & Vent Plan, Drawing No. M-L 27 70/19 (April 1947).

Lock and Dam No. 26R depict a wholly utilitarian structure devoid of architectural ornamentation or detailing.[87]

Only two lockkeepers' houses were constructed as part of the Upper Mississippi River Project in the St. Louis District. Located at Lock and Dam No. 25, the two houses and their shared garage are identical to the houses located at installations in other Districts. The construction drawings, dated August 1938, are signed by Associate Engineer Marshall Gray, designer of the Central Control Stations at Lock and Dam Nos. 24 and 25. The lockkeepers' houses bore scant resemblance to the streamlined, industrial appearance of the Control Stations. They were two-story wood frame Colonial Revival style dwellings with pedimented doorways. The single story garage also displayed Colonial Revival stylings.[88] The original garage was replaced by the present structure in May 1974, while both houses were sold to a private citizen and removed from the site to an unknown location in June 1984.

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[87]Mississippi River Lock and Dam No. 26 (Replacement), Auxiliary Lock and Remainder of Dam Control House -- Elevations, Drawing No. M-L 26(R) 92/2 (n.d.).

[88]Mississippi River Lock & Dam No. 25, Lock-Keepers' Dwellings -- Elevations and Wall Section, Drawing No. M-LG 74/1 (August 1938); Ibid., Garages, Drawing No. M-LG 76/11 (August 1938).

The construction process, and the decisions related to that process, greatly influenced the pace of technological innovation at the individual construction sites. Poor or misguided construction decisions invited disaster, while well-planned and well-executed construction efforts often generated technical innovations and improvements incorporated into work at later sites. The following pages offer detailed descriptions of the construction process at Lock and Dam No. 26 and Lock No. 25, as well as a brief description of the construction of Lock and Dam No. 27 and the Chain of Rocks Canal. These descriptions provide information on the methods used to construct the individual structures, both efficient and inefficient, and indicate the range of minor technical innovation and improvement realized during the course of construction.

The main lock at Alton, Illinois, part of Lock and Dam No. 26, constituted the St. Louis District's first experience with the massive construction projects required to construct a 9-foot channel on the Upper Mississippi River. The lessons learned during the difficult and occasionally disastrous course of the construction of the main lock provided the District engineering staff with valuable experience, which they applied to the other projects constructed in the District. The Corps' final report on the construction of the main lock discusses in detail many of the problems that plagued the project and delayed its completion.

Lock and Dam No. 26 is located at Alton, Illinois, approximately twenty-three miles above St. Louis, immediately upstream from the bridges of the Missouri & Illinois Bridge & Belt Railway and the Clark Highway. The twin locks are located along the Illinois bank of the river and incorporate two of the bridge piers in the intermediate wall.

This installation, like the others proposed for the St. Louis District, was considered of the lowest priority by the Corps of Engineers' special board of survey. However, because the pool created by the dam would create backwater eighty miles up the Illinois River, which entered the Mississippi approximately twenty miles above the dam, this installation became the first portion of the 9-Foot Channel Project constructed in the District. Lock and Dam No. 26 facilitated the movement of barge traffic on both the Mississippi and the Illinois Rivers, thus making the installation a key element within a complex inland navigation system that ultimately extended from New Orleans to Pittsburgh, Chicago, Kansas City, and Omaha.

Lock and Dam No. 26 was constructed between 1934 and 1938, and the installation opened to navigation in May 1938. The locks consist of a main chamber measuring 110 feet by 600 feet and an auxiliary chamber of 110 feet by 360 feet. The movable portion of the dam is 1,725 feet in length and consists of thirty Tainter gates, each forty feet wide, and three roller gates, each eighty feet wide. An earthen dike extends at an angle from the Missouri dam abutment approximately 900 feet to the embankment of the Missouri & Illinois Bridge & Belt Railway.[89]

Throughout the course of the 9-Foot Channel Project the construction of the navigation locks preceded construction of the dam.[90] A cofferdam surrounded the construction site and enabled the work area to be pumped dry so that the locks could be constructed "in the dry," while traffic passed along the river outside the cofferdam. Upon completion of the locks the cofferdam was removed and traffic could proceed through the open lock chambers while work progressed on the dam.

The special board of survey initially recommended that Lock and Dam No. 26 be located just below Grafton, Illinois, approximately one mile below the mouth of the Illinois River.[91]

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[89]Mudd, "Locks & Dam No. 26," p. 1.

[90]The exception to this rule is at Lock and Dam No. 26R, where the western portion of the dam was constructed prior to the main lock.

[91]House Doc. 137 (1932), p. 120.

However, by September 1933 the site had been relocated downstream to Alton, Illinois.[92] Alton's mayor, Tom Butler, claimed forty years after the fact that the Corps relocated the dam because the Grafton site did not have the open space required for an adequate materials storage and staging yard. Butler claimed that Corps engineers proposed to relocate the lock and dam at Alton, where a recently constructed riverside park offered an excellent site for a construction yard, if the city agreed to grant the land to the government without rent for the duration of the project. Faced with large scale unemployment and the other economic consequences of the Great Depression, the city government quickly agreed to this proposition.[93]

It seems likely that the location of the locks at the Alton end of the dam resulted from Mayor Butler's lobbying. Placing the locks at this end of the dam helped the city's economy, but makes little sense from a strict engineering point of view. The

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[92] Alton (Illinois) Evening Telegraph (September 13, 1933), p. 1. Such relatively minor relocation of lock and dam sites proved common throughout the course of the project. The initial recommendations of the special board of survey were frequently discarded upon closer investigation. Rathbun Associates, "HAER Documentation," pp. 32-34.

[93] Journal of Wood River Township (March 13, 1975). Clipping on file at Hayner Public Library, Alton, Illinois; Alton (Illinois) Evening Telegraph (September 15, 1933), p. 1; Ibid. (September 16, 1933).

locks are awkwardly located, their alignment in the river determined by the need to incorporate two existing bridge piers into the lock walls, which creates a difficult approach into the lock chambers for tows.

The Upper Mississippi Valley Division designed the twin locks at Lock and Dam No. 26. William H. McAlpine, the Division's Head Engineer, signed the construction drawings, which are dated October 1933, shortly after the Corps secured the Alton construction site. The site held the potential for creating scour at the existing railroad and highway bridges both during cofferdam construction and normal operation. Between 1933 and 1936 the Corps conducted model tests on the structure at the University of Iowa's Hydraulic Laboratory. These tests led the engineers to design extensive stone and timber mattresses to protect the bridge piers from scour.[94]

In November 1933 the Corps of Engineers put Mississippi River Twin Lock No. 26 out for bid. The five bids were opened on December 19, 1933, and that of John Griffiths & Son Company, of Chicago was the lowest. Griffiths & Son's nearly $3.2 million bid was almost $200,000 less than the next lowest and approximately $350,000 less than the government estimate for the

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[94]Mudd, "Locks and Dams No. 26," p. 2.

job. Griffiths & Son had an established reputation as large scale contractors, having built both the massive Merchandise Mart and the main United States Post Office building in Chicago. However, the firm had virtually no experience in the highly specialized field of river construction.[95] Despite this lack of experience, Griffiths & Son received notice to proceed on the construction of Lock No. 26 in mid-January 1934.[96]

The public works aspects of the job became apparent almost immediately after its official announcement. In December 1933 a controversy erupted between Missouri and Illinois politicians regarding the composition of the project's work force. Senator Clark, of Missouri, declared that the labor force would be split equally between residents of Missouri and Illinois. Alton mayor Tom Butler filed a protest with the Labor Department and wrote his senators. Butler argued that during the negotiations with the Corps for the use of Riverside Park he had been led to believe that the ratio of Illinois to Missouri residents on the work force would be three to one. Butler argued that Madison County, Illinois had a population six times that of largely rural and agricultural St. Charles County, Missouri, and six

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[95] Journal of Wood River Township (March 13, 1975).

[96] "Final Report -- Lock and Dam 26, Part I," p. 1. Alton (Illinois) Evening Telegraph (December 19, 1933), p. 1.

times the number of unemployed. Ultimately, Butler's arguments carried the day.[97]

Griffiths & Son relied almost entirely upon local laborers, importing only fifteen to twenty key personnel from Chicago. The number of Chicago-based personnel at the job site varied throughout the course of the job. Workers were hired at prevailing union rates for the St. Louis metropolitan area, with common laborers earning sixty cents an hour, but the unions involved in the job maintained that the predetermined wage scales were below the regular rates for their work and refused to furnish workmen. In May 1934 the Wage Predetermination Board of the Department of Labor ruled in favor of the unions and held that common laborers should be paid at a minimum rate of sixty-seven and one-half cents per hour. Griffiths & Son estimated that this rate increase would raise the cost more than $40,300. The Corps of Engineers agreed to cover this increase.[98]

Prior to the notice to proceed the Illinois Terminal Railroad laid spur tracks and sidings in the future construction yard at Riverside Park. Griffiths & Son received approval of their cofferdam design in mid-January 1934, and on February 1, 1934,

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[97] Alton (Illinois) Evening Telegraph (December 23, 1933), p. 1; "Final Report -- Lock and Dam No. 26, Part I," p. 8.

[98] "Final Report -- Lock and Dam No. 26, Part I," p. 7.

under the supervision of Construction Manager Julius R. Hall and his assistant, Don S. Willey, Griffiths & Son crews began construction of the main lock cofferdam.[99]

This cofferdam was designed in a heavier and stronger fashion than dictated by common practice because the presence of the existing swing span railroad bridge required that traffic pass through the area of the auxiliary lock during construction of the main lock. This dictated that the river arm of the main lock cofferdam be placed very near the intermediate lock wall, preventing construction of a suitable stabilizing berm on the inside of the cofferdam.[100]

The main lock cofferdam enclosed approximately thirteen acres behind a wall of semi-circular steel sheet pile cells filled with dredged material. Y-connection piles, connected to two structural frames, tied the individual cells together at the panel points. Outside wall piles measured fifty-five feet in length, while inside wall piles were forty feet long. The construction methods adopted by Griffiths & Son for the cofferdam corresponded closely to land work practice. A wood

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[99] Alton (Illinois) Evening Telegraph (January 9, 1934), p. 1; Ibid. (January 22, 1934), p. 1; "Final Report -- Lock and Dam No. 26, Part I," pp. 9, 13, 14.

[100] E. P. Ketchum, "Removing a Collapsed Cofferdam," The Military Engineer, 29 (May-June 1937): 203.

pile-supported trestle was first constructed along the center line of the cofferdam. Railroad tracks atop the trestle supported a succession of derricks and cranes that aided in the construction of the sheet pile cells and the delivery of materials. Construction of the trestle began in early February 1934 and was completed by mid-April. Placement of the steel sheet piling began in early March, and was completed by the end of April.[101]

While construction progressed on the cofferdam L. B. Feagin conducted his tests of the load capacities of the wood and concrete friction piles designed to support the structure. The bed of the Mississippi at Alton consists of a minimum of eighty feet of sand above bedrock, forcing construction of the structure atop a pile foundation not driven to bedrock. The river bed also proved particularly susceptible to scour, which threatened to undermine the cofferdam. A pair of streamlined pile fins helped to smooth the flow of water around the cofferdam, presumably reducing scour, while ballasted brush and timber mattresses placed against the cofferdam held the foundation soil in place. The unwatering of the cofferdam began in early May 1934 and serious seepage problems developed almost

[101]"Final Report -- Lock and Dam No. 26, Part I," pp. 29-30; Carl Stopp, "Report of Main Lock Cofferdam Twin Locks No. 26, November 1934," pp. 2-5. Typescript report on file at St. Louis District Office, U.S. Army Corps of Engineers.

immediately. This seepage stemmed principally from percolation passing beneath the cofferdam cells. In early June installation of an extensive system of wellpoints within the cofferdam, which lowered the water surface one to two feet below grade, checked the seepage and permitted work in the dry.[102]

By mid-May unwatering had advanced to the point that a pile driver began placing foundation piles for an interceptor sewer designed to carry Alton's existing Piasa Street sewer below the locks. The first piles for the lock's land wall were driven in early June, and in mid-June work began on the intermediate wall foundations. With the exception of the piling for some of the struts between the lock walls, all pile driving within the main lock cofferdam was completed by the end of October 1934.[103]

Pile driving operations were conducted using three 6-hour shifts, five days a week. Four pile drivers were in daily operation after the middle of June, with a fifth unit held in

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[102]The well-point system represented an advance over previous methods, which relied upon large surface pumps to discharge water from sumps. The new system cost more, but afforded a drier work area. It appears to have been first adopted on the Upper Mississippi River Channel Project in the Rock Island District ca. 1933. Herbert G. McCormick and John W. Dixon, "Mississippi River Cofferdams," The Military Engineer, 28 (March-April 1936): 105-108; "Final Report -- Lock and Dam No. 26, Part I," p. 31; Stopp, "Main Lock Cofferdam," pp. 5-6.

[103]"Final Report -- Lock and Dam No. 26, Part I," p. 35.

reserve. Each rig placed an average of thirteen piles in a shift. The majority of the piles consisted of eleven-inch diameter, thirty-two-foot long wood piles. Three rows of tapered, thirty-two-foot concrete piles were placed on the river side of both the land and intermediate walls.[104]

A single row of forty-foot steel sheet piling was driven along the outside of the land wall, below the upper miter sill, and through the center of the intermediate wall to act as a cutoff wall and prevent the foundation sand from being carried away by scour or an uncontrolled flow of water beneath the structure. Loss of this sand would remove the lateral and vertical support from around the piles, creating an overstressed condition and the possibility of a total structural collapse. Driving of the steel sheet cutoff walls began in late June 1934.[105]

Unlike the remainder of the lock structure, the upper end of the land wall is founded on a rock-filled timber crib surrounding fifty-six-foot wood piles. Construction of this cribbing began

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[104]Ibid., pp. 35-37. Concrete piles appear to have been used at both Lock No. 26 and Lock No. 25, the two pile-founded lock installations constructed in the St. Louis District during the 1930s. The concrete piles were placed in areas that supported heavy loads, principally at the edges of the lock walls and at the junctures between the walls and the miter gate sills. The installations constructed in the Rock Island and St. Paul Districts during this period do not appear to have utilized concrete piles.

[105]Ibid., p. 38; Mudd, "Locks and Dam No. 26," p. 4.

in mid-September 1934. Below the reinforced concrete apron in front of the lower discharge ports derrick stone protection was laid directly atop the sand between the concrete struts to prevent scour. This protection, four feet deep and thirty feet wide, was largely placed from atop the intermediate wall.[106]

Griffiths & Son located the central concrete mixing plant on shore. The plant consisted of a pair of two-yard Smith mixers with attendant aggregate and bulk storage bins. As work progressed, two auxiliary mixing plants were erected on shore at either end of the construction site.[107]

Griffiths & Son determined to place the concrete using a large number of belt conveyor units stored in their Chicago material yard. This decision eliminated the need for heavy gantry cranes, which precluded the use of large, heavy concrete forms. The capacity of the mixing plant exceeded that of the conveyors. With the plant running at capacity concrete pyramided in the forms, forcing a delay of several minutes while the material was shoveled down and vibrated into place.[108]

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[106]"Final Report -- Lock and Dam No. 26, Part I," p. 39.

[107]Ibid., p. 40.

[108]Ibid., p. 41.

The decision to utilize belt conveyors affected many aspects of the work. The absence of heavy gantry cranes at the job site led Griffiths & Son to adopt small, easily handled forms that produced small five-foot tall monoliths containing only ninety to two hundred yards of concrete.[109] A standard day's production required the completion of five to eight of these monoliths, which placed considerable strain upon the complex belt conveyor distribution system, which had to be shifted each time work began on a new monolith. The Corps of Engineers estimated that the light concrete forms and the belt conveyor concrete distribution system added approximately $1.50 to the cost of a cubic yard of concrete over and above the cost of placement using gantry cranes and concrete buckets.[110]

Concrete placement began in mid-August 1934. Griffiths & Son planned to construct the lock walls in a pyramidal fashion, broadening the base as the upper pours advanced. Throughout August concrete placement continued at the rate of one footing monolith per day. The small amount of yardage contained in the monoliths produced by Griffiths & Son, and the large amount of

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[109]Corps of Engineers specifications for the locks required monoliths a maximum of forty feet long with a minimum thickness of four feet and a maximum thickness of eighteen feet. The five-foot Griffiths & Son monoliths barely complied with these specifications. Ibid., p. 44.

[110]Ibid., pp. 41, 46-47.

carpentry work required to form each monolith, retarded production and prevented placement of more than seven hundred yards per day. The high form costs and disappointing progress led the monolith heights to be increased to ten, and later fifteen, feet beginning in November 1934. Concrete placement continued, hampered by Griffiths & Son's decision to utilize the belt conveyors, well into 1935.[111]

The delays in concrete placement caused a delay in the start of steel erection, since the latter could not proceed until completion of the top concrete lifts at the gate bays, which included the gate anchorages. Steel erection began in mid-February 1935, when a Griffiths & Son crew began erecting the upper gate leaf for the intermediate wall. Riveting of the upper gate leafs began in early March, and the erection of the lower gate began near the end of April.[112]

Corps of Engineers personnel at the site complained that Griffiths & Son's steel erection lacked organization and planning. Riveting gangs failed to follow closely upon the erection gang, despite repeated insistence on the part of the government engineers. Lack of cranes, and other hindrances

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[111]Ibid., pp. 41, 44-49.

[112]Ibid., pp. 50-51.

greatly delayed this phase of the construction. In March 1935 the river overtopped the cofferdam, placing four to twelve inches of silt on the lock floor and further complicating the work.[113]

Construction of the main lock was completed by late September 1935 and work began on the removal of the main lock cofferdam. The heavy construction of the cofferdam delayed its removal, and consequently delayed the start of the auxiliary lock cofferdam, which could not interfere with river traffic until that traffic could pass through the completed main lock.[114]

In early October 1935 Griffiths & Son's crews began constructing the river arm of the auxiliary lock cofferdam, and completed both the river and lower arms of the structure by mid-December. The contractor closed off the lower arm in hopes that the river would deposit the two to eight feet of fill required to bring the auxiliary lock site up to grade, despite the recommendations of the Corps of Engineers' Resident Engineer, H. S. Pence, against this unorthodox practice.[115]

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[113] Ibid., p. 50.

[114] Ibid., p. 14.

[115] Ketchum, "Removing a Collapsed Cofferdam," p. 203; "Final Report -- Lock and Dam No. 26, Part I," pp. 52-53.

On December 19, 1935 the temperature fell sharply, and on December 20 heavy ice started to run in the river. By December 26 the auxiliary cofferdam had filled with ice. The ice damaged a portion of the river fin, an extension of the cofferdam designed to streamline the flow of water around the structure, in early January, and repair efforts proved unsuccessful. As a stopgap, a barge loaded with derrick stone was placed against the fin to protect it from the flowing ice. Cofferdam driving resumed on January 15, 1936, and all but three cells in the upper arm of the cofferdam were completed before cold and ice again halted the work on January 17.[116]

Extremely low temperatures prevailed throughout the end of January, and by the end of February the entire river was gorged with heavy ice. On the night of February 26 a large gorge upstream from the lock broke up and considerably damaged the fin on the lock side of the cofferdam. On February 29 the river fin failed completely and the sheet pile cells of the cofferdam began to collapse like dominos. By March 22 Cells No. 8-36, almost the entire upper and river arms, had totally failed. In

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[116]Ketchum, "Removing a Collapsed Cofferdam," p. 203; "Final Report -- Lock and Dam No. 26, Part I," p. 53.

addition to the cofferdam, a crane, a steam hammer, and assorted other material plunged into the river.[117]

Following the collapse of the auxiliary lock cofferdam Griffiths & Son began to disband their work force and remove their equipment from the job site. On March 18, 1936, in reply to a telegram from the District Engineer, Griffiths & Son held that it was not obligated to assume the construction hazard associated with completion of the auxiliary lock, since the District Engineer had ordered the Engineering Construction Corporation, the contractors for construction of Dam No. 26, to proceed with the second section of the dam cofferdam. The District Engineer notified Griffiths & Son of the government's intention to terminate their contract on April 2, 1936, and on April 7 Griffiths & Son notified the Corps that it had abandoned the work and would proceed to remove its equipment and material.[118]

The termination of the contract left the Corps of Engineers with responsibility for removing the collapsed cofferdam and preventing damage to the completed main lock. In late April

[117] Ketchum, "Removing a Collapsed Cofferdam," p. 203; "Final Report -- Lock and Dam No. 26, Part I," pp. 54-55.

[118] Ketchum, "Removing a Collapsed Cofferdam," p. 204; "Final Report -- Lock and Dam No. 26, Part I," pp. 57-58.

1936 Corps personnel constructed and placed 820 feet of timber mattress against the intermediate lock wall to prevent scour. Throughout May 1936 Corps equipment and crews removed the standing cells of the auxiliary lock cofferdam to prevent eddies and facilitate the passage of river traffic.[119]

In June 1936 work began on the attempt to precisely locate the collapsed cofferdam. Knowledge of the location and depth of the collapsed cells was essential to the development of a plan for their removal and to avoid delaying the dam contractor, who was expected to complete work within his second cofferdam by the late fall of 1936. Divers successfully located the cells, laying nearly horizontal beneath eight to eighteen feet of sand.[120]

W. F. Goodson, one of the engineers engaged in the raising of the battleship Maine from the bottom of Havana Harbor, and then assigned to the Buffalo District of the Corps of Engineers, was brought in to assist in the removal effort. Dredges removed the sand atop the collapsed cells, divers attached shackles to the sheets, and these were hauled free in groups of twelve to twenty by a derrick boat. The work was terminated, with most of the

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[119]"Final Report -- Lock and Dam No. 26, Part I," p. 59.

[120]Ibid., p. 60; Ketchum, "Removing a Collapsed Cofferdam," pp. 204-206.

collapsed cells completely removed, in late September 1936. The dam contractor located his third cofferdam, which included this area, in such a fashion as to avoid any unrecovered sheets. The removal of the cofferdam was effected with remarkable speed, partly because of the abnormally low water levels experienced during 1936, and the dam contractor was provided with access to the area on schedule in November 1936.[121]

The failure of Griffiths & Son to complete their contract provided the engineers of the St. Louis District with valuable information regarding the appropriate manner in which to approach construction projects of this magnitude. The low unit bid prices submitted by Griffiths & Son required that the most efficient equipment and operational plan be utilized if the job were not to prove a tremendous financial loss to the firm. However, Griffiths & Son developed their plan on the basis of the equipment on hand, rather than on the use of the most suitable and efficient equipment. Likewise, the firm, though inexperienced in river construction, made no attempt to secure the services of an experienced superintendent.[122]

[121]"Final Report -- Lock and Dam No. 26, Part I," pp. 61-62; Ketchum, "Removing a Collapsed Cofferdam," pp. 204-206.

[122]"Final Report -- Lock and Dam No. 26, Part I," pp. 55-56.

The organization of the construction plan failed to take into account the complexities of the job. Inattention to dredging the subgrade within the cofferdam required the removal of large amounts of fill by dragline, which, along with inadequate control of pumping, delayed pile driving. A lack of planning in the layout of the piling delayed preparation of the foundations at the gate bay areas, consequently delaying the placement of concrete and the erection of the miter gates. Corps engineers estimated that use of a twenty-four-hour construction day would have sped construction to the point that all work within the first cofferdam could have been completed by April 1935, five months ahead of the actual completion date. Completion of the main lock in April would have permitted completion of the auxiliary lock cofferdam prior to the onset of river ice, thus avoiding the disastrous cofferdam failure experienced in March 1936.[123]

As previously noted, Griffiths & Son's decision to place concrete using belt conveyors significantly affected the project. By eliminating the need for gantry cranes to handle concrete buckets, Griffiths & Son were compelled to rely upon lightweight forms that slowed construction and proved inordinately costly.

[123] Ibid., p. 56.

The Corps issued the advertisement for bids on the construction of Dam No. 26 in mid-March 1935, as work neared completion on the main lock. Senior Engineer A. F. Griffin of the Upper Mississippi Valley Division signed the December 1934 construction drawings for the dam. The specifications called for a 1,724-foot long movable dam consisting of three steel roller gates, each twenty-five feet deep and eighty feet long, and thirty submergible steel Tainter gates, each forty feet long and thirty feet high. The roller gates occupied the central portion of the dam and were flanked on either side by fifteen Tainter gates. Individual electrically-driven gear reduction units, mounted either on the roller piers or beneath the service bridge spans, raised and lowered the roller and Tainter gates, respectively. A steel deck girder service bridge extended across the entire length of the dam and 154 feet onto the Missouri abutment, which contained a concrete-paved storage yard. A seventy-five-ton locomotive crane was mounted on rails atop the service bridge.[124] An earth dike, adjoining the Missouri

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[124]The original plans called for the use of two cranes on the service bridge. These plans were changed after the award of the dam contract. This design modification necessitated the provision of tracks in the Missouri abutment storage yard for the storage of the emergency bulkheads. Ibid., p. 22.

abutment at an angle, extended nearly nine hundred feet to the embankment of the Missouri & Illinois Bridge & Belt Railway.[125]

The Corps of Engineers received four bids for the project, with that of the Engineering Construction Corporation proving to be the lowest. This firm, incorporated in Delaware, consisted of a joint venture by George A. Fuller & Company, Turner Construction Company, and Spencer, White, & Prentiss for the purposes of securing the Dam No. 26 contract. Engineering Construction Corporation's bid of nearly $4.9 million was almost $200,000 less than the next lowest bid, but $650,000 above the government estimate for the job.[126]

Frederick B. Spencer served as Engineering Construction's on-site manager, while R. J. Dunlap acted as Superintendent. The Engineering Construction staff varied between thirty and thirty-five experienced specialists, in addition to locally hired labor.[127]

Government supervision for the dam contract remained in the hands of the St. Louis District's Lock and Dam Section. Captain

[125]"Final Report -- Lock and Dam No. 26, Part II," p. 1.

[126]Ibid., p. 1.

[127]Ibid., pp. 5-6.

W. W. Wanamaker commanded the section, which was headquartered in Alton, until September 1935, when he was reassigned and replaced by Major E. P. Ketchum. L. B. Feagin served as Senior Engineer, in charge of construction and design, with J. A. Adams as his assistant. At the time of Ketchum's appointment the Lock and Dam Section, including Ketchum, Feagin, and Adams, was moved to the District Engineer's Office in St. Louis. An on-site office was established at Alton, with H. S. Pence as Resident Engineer.[128]

The Engineering Construction Corporation received notice to proceed in mid-June 1935.[129] The firm immediately established a construction plant on the Missouri shore. The plant arrangement was based upon the experience of the member firm, Spencer, White, & Prentiss, who had recently completed Lock and Dam No. 6 at Trempleleau, Wisconsin and who, at the start of this contract, were constructing Lock No. 3 at Red Wing, Minnesota. The plan developed by the Corps of Engineers called for the dam to be constructed within three cofferdam units, necessitating the use of a floating concrete plant. Accordingly, the contractor designed their entire plant according to generally

[128] Ibid., p. 7.

[129] Ibid., pp. 1, 8.

accepted principals of marine construction, in marked contrast to the land-based principals adopted by Griffiths & Son.[130]

The first cofferdam enclosed an area that included the site of the Missouri abutment and the twelve Tainter gate bays adjacent to the abutment. Work began on this cofferdam in late June 1935, having been delayed by high water conditions. The cofferdam consisted of two rows of interlocking steel sheet piling, ranging in length from thirty-seven to sixty feet, spaced thirty feet apart and connected by tie rods. Sand filled the space between the two rows of sheet piling and was bermed against both the outside and inside walls. Timber guide piling carried the templates for the steel sheet piling. By mid-August, after forty-five working days, the cofferdam was completed and unwatering began.[131]

By the end of August the cofferdam had been unwatered and the driving of the dam's timber pile foundation begun. A total of 5,100 wooden piles were driven between this time and mid-December, at an average rate of nearly three piles per hour for each of the two driving rigs.[132]

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[130] Ibid., p. 26.

[131] Ibid., pp. 30-31.

[132] Ibid., p. 38.

A continuous, 47.5-foot deep, steel sheet-pile cutoff wall extended across the entire length of the dam above the piers. A second cutoff wall, 24.5-feet deep, was located at the downstream edge of the stilling basin. Transverse walls of sheet piling connected the upstream and downstream cutoff walls every ninety-six feet. The cutoffs were intended to prevent water from percolating through the sand foundation beneath the dam; however, subsequent experience indicates that they were underdesigned and that the drains provided to relieve uplift pressure failed to function as intended.[133]

Concrete placement in the first cofferdam began in mid-October 1935. A floating concrete plant, consisting of a pair of 1.5 cubic yard Ransome mixers with accompanying scales, hoppers, and bins, supplied the concrete for the forms. From the mixers a series of belt conveyors carried the concrete over the cofferdam and discharged it into a large hopper that spanned a pair of industrial locomotive tracks. Concrete from this hopper was released into sixty-two-cubic-foot dump buckets placed on flat cars. A locomotive hauled the cars to the gantry cranes, which lifted the buckets to the point of placement.[134]

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[133] Ibid., p. 39; Mudd, "Lock and Dam No. 26," p. 4.

[134] "Final Report -- Lock and Dam No. 26, Part II," pp. 9, 40-41.

The use of gantry cranes and dump buckets enabled the Engineering Construction Corporation, unlike Griffiths & Son, to use heavy concrete forms handled by the cranes. The Corps of Engineers highly praised the "sturdy and good construction" of the forms prepared by Engineering Construction Corporation member firm, the Turner Construction Company, who had more than thirty years experience in concrete construction.[135]

Form construction began in August 1935, prior to the unwatering of the cofferdam. Tongue and groove flooring was used as sheathing for the forms, which included permanent staging and ladderways. Two complete sets of Tainter pier forms were prepared to speed production. Stripping the forms, moving them, and resetting them by gantry crane initially required approximately twelve hours. As the work progressed it ultimately became possible to accomplish this task in as few as six hours.[136]

The method of concrete placement underwent minor modification during the course of construction. Piers 29 and 31 in the first cofferdam were placed in accordance with the contract

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[135] Ibid., p. 45.

[136] Ibid., pp. 45-46.

specifications, which called for two separate lifts. Tests on these piers showed no fatigue or form distress, and it was determined to place the next pier continuously to full height. The experiment proved successful, and permitted elimination of the twenty-two to twenty-four hours of rest time previously required between lifts, increasing the rate of construction to two piers per week.[137]

The American Bridge Company served as subcontractor for steel fabrication and erection. The firm established its field office at the site in mid-October 1935, and began erecting the steel eye bar assemblies for Gates 28 and 29 in late November. American Bridge originally planned to transport structural steel members into the cofferdam by means of the service bridge, which would be advanced ahead of the work. However, earth slides along the Missouri abutment delayed the start of work on the service bridge and forced American Bridge to erect a temporary trestle to span the caved area. Erection of the service bridge did not begin until January 1936. However, to prevent a delay in the erection schedule, members for the Tainter gate A-frames were brought by rail onto the lower arm of the cofferdam, and moved into the gate bays by the general contractor's gantry

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[137] Ibid., pp. 46-47.

cranes. American Bridge Company crews erected the steel within the bays.[138]

United Construction Corporation crews placed all the reinforcing and embedded anchorage assemblies for the Tainter gates. The trunnion pins, on which the gates moved, were placed and aligned by American Bridge Company crews, and the enclosing stirrups later pre-stressed, under a 500,000 pound load, to the embedded anchorage assembly.[139]

Work within the first cofferdam was completed by the end of February 1936. Removal of the steel sheet piling began in early March and was completed by the end of May. This material was reconditioned for use in the second cofferdam, which had been begun in early February 1936.[140]

The second cofferdam slightly overlapped the first and enclosed an area for the construction of six Tainter gates and the three roller gates. Its design and construction corresponded to that of the first cofferdam, with the overlapping section used as a locking chamber for the storage of forms, cranes, and other

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[138]Ibid., p. 48.

[139]Ibid., p. 48.

[140]Ibid., pp. 9, 31.

construction equipment. The cofferdam was closed in mid-May 1936, despite a failure of the guide piling and trestle work of the upper arm at the beginning of the month, and the last of the steel sheet piling was driven during early June.[141]

Unwatering of the second cofferdam began in mid-June 1936. A unique feature associated with this process was the use of a floating crane and pile driver within the cofferdam. These rigs spread stone for the inside berms and drove the piles for the Gantry crane trestles prior to the completion of unwatering. The Corps of Engineers estimated that this innovation saved ten to fifteen days of work.[142]

Pile driving in the second cofferdam began in late June 1936, with the first placement of concrete occurring about a month later. American Bridge Company crews began erection of the Tainter gates in early August, and a month later started erecting the three roller gates. By the end of October 1936 work within the second cofferdam had been completed and by early December the cofferdam had been removed.[143]

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[141] Ibid., p. 31.

[142] Ibid., p. 32.

[143] Ibid., pp. 9, 32.

The principal change in construction procedures between the work conducted in the first cofferdam and that in the second stemmed from the American Bridge Company's full use of the service bridge for both the delivery of steel into the cofferdam and as a base for the guy derrick used to erect the steel.

The roller gates were partially shop-assembled at the American Bridge Company plant and shipped to the construction site for field erection.[144] The roller gate operating machinery was shop-assembled and erected atop the piers prior to the construction of the poured-in-place operating houses. Falsework supported the gate sections during the erection process. The end sections were erected first and carefully positioned in the pier recesses in their precise operating positions. The central section was then erected and bolted to the ends. The entire gate was aligned, the apron placed, the gate riveted and realigned, and the inclined racks in the pier recesses lined, leveled, and grouted into place. After the grout had set, the hoist chain was connected and adjusted, the gate rolled up, and the falsework dismantled. The gate was then rolled down into its closed position to check the alignment of the seal with the gate

[144]Tainter gates appear to have been almost entirely assembled in the field.

sill, and the end shields were straightened and realigned into their final position.[145]

Construction of the third cofferdam began in late September 1936. This final section of cofferdam enclosed the remainder of the dam area and the site of the auxiliary lock. The upper arm of the cofferdam was closed without incident in mid-November. The lower arm was closed approximately a month later and unwatering operations started immediately.[146]

The design of the third cofferdam included a provision for flooding the dam in case of abnormally high water. In early March 1937, and again in early May this emergency flume was utilized to prevent overtopping of the dam.[147]

Work in the third cofferdam progressed in the same fashion as previously described. Pile driving began in mid-December 1936 and was essentially completed by the end of April 1937. Concrete placement began at the end of January 1937. The American Bridge Company began erecting Tainter gate steel in

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[145] "Roller-Gate Dam Erection," pp. 412-414.

[146] "Final Report -- Lock and Dam No. 26, Part II," pp. 32-33.

[147] Ibid., pp. 33-34.

mid-April and at one time managed to complete two gates per week.[148]

The Central Control Station for Lock and Dam No. 26 is located on the river wall against the dam. Originally designed to be constructed of reinforced concrete, Corps engineers determined, based upon experience gained at other Mississippi River Project sites, that this type of construction tended to crack and check in thin building walls and permitted objectionable condensation on the building's interior walls. Accordingly, the Control Station was redesigned as a brick and tile building with a structural steel frame. Work on the Control Station began in mid-July 1937 and was completed by mid-December.[149]

Work within the third cofferdam was completed by the end of September 1937. Removal of the sheet piling was completed by the end of December 1937 and on January 21, 1938 the government accepted the project and declared the contract completed.[150]

The government's experiences during the construction of the dam and auxiliary lock at Lock and Dam No. 26 proved much more

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[148] Ibid., pp. 34, 38, 48.

[149] Ibid., p. 49.

[150] Ibid., p. 10.

satisfactory than those associated with the construction of the main lock. The government highly praised the experience and efficiency of the member firms of the Engineering Construction Corporation in its "Final Report" on the project.[151] The experience gained during work on Dam No. 26 convinced engineers in the St. Louis District that planning and experience were as important, if not more so, than price in determining that a large scale construction project was completed on schedule and on budget. All future work in the District was accomplished by firms experienced in river construction.

Lock and Dam No. 25 constituted the second element of the Upper Mississippi 9-Foot Channel Project constructed in the St. Louis District. The Emergency Relief Appropriation Act of April 1935 released funds for construction of the project. The construction of the lock structure stands in sharp contrast to that described above for Lock No. 26, being conducted in a far more efficient manner.[152]

The special board of engineers recommended the construction of four locks and dams within the St. Louis District. Detailed

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[151] Ibid., p. 50.

[152] St. Louis District, Corps of Engineers, "Mississippi River Lock & Dam No. 25 -- Final Construction Report, Volume I, Lock No. 25" (St. Louis: Corps of Engineers, ca. 1943), p. 3. Hereafter cited as "Final Report -- Lock and Dam No. 25, Volume I."

studies completed after publication of the board's final report indicated that Lock and Dam No. 23 could be eliminated from the project, which necessitated the relocation of Lock and Dam Nos. 24 and 25. Initial site investigations for Lock and Dam No. 25 centered on the vicinity of River Miles 239 and 240. The final site chosen for the project was Mile 241.5, at Bradley Island, near Cap au Gris, Missouri.[153]

The completed project consisted of a main lock and the upper gate bay of an auxiliary lock, an earth dike extending upstream approximately five miles along the Missouri shore from the upper guide wall of the lock to Kings Lake Levee, a dam containing a movable section made up of fourteen Tainter gates and three roller gates, a fixed submersible stone-covered earth dike extending to the Illinois shore, lockkeepers' dwellings, and a roadway connecting Bradley Island to the Missouri shore.[154]

The Corps of Engineers advertised for bids for the construction of Lock No. 25 in mid-April 1935. Five bids were received and the contract was awarded to the low bidder, the United Construction Company of Winona, Minnesota. United Construction's $2.1 million bid was only $60,000 less than the

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[153] "Final Report -- Lock and Dam No. 25, Volume I," p. 3.

[154] Ibid., p. 4.

next lowest bid, and $170,000 below the government estimate for the job. The contract between the federal government and United Construction was approved in early November 1935 and work started immediately.[155]

The Corps of Engineers' Upper Mississippi Valley Division prepared the design and construction drawings for the lock. The design drawings, signed by A. F. Griffin, Principal Engineer for the division, are dated August 1935. The Lock and Dam Section of the St. Louis District Office, under Major E. P. Ketchum, prepared the specifications, administered the contract, and supervised construction. L. B. Feagin served as Senior Engineer within the District's Lock and Dam Section, assisted by J. A. Adams. C. E. Pehl served as the Corps' Resident Engineer for the project.[156]

The design for Lock No. 25 conformed to standard 9-Foot Channel Project practice and included a main lock, the upper gate bay of an auxiliary lock, and upper and lower guide walls. The auxiliary lock, if completed, would have measured 110 feet by 360 feet. However, the only portions of the auxiliary lock constructed were the upper gate bay, with its thirty-five-foot

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[155] Ibid., pp. 9-10.

[156] Ibid., pp. 9, 34.

miter gates, and the recesses in the intermediate wall for the lower miter gate and its machinery. Manholes and crossovers for electrical and other services were also provided. The contract for the lock construction included placement of the esplanade fill, an earth dike extending from the end of the upper guide wall to the upper end of Bradley Island, the roadway connecting Bradley Island to the Missouri shore, and a portion of the dam sill for Tainter gate No. 1.[157]

The lock walls consist of forty-four-foot tall gravity sections of reinforced concrete supported on steel and timber piles. Steel wall armor embedded in the vertical surfaces of the lock walls protects the concrete from tow and barge collisions. The land and intermediate walls contain longitudinal culverts or tunnels for filling and emptying the main lock. The culverts are twelve and one-half feet square at the Tainter valves and fourteen feet in diameter between the valves. Water enters and leaves the lock chamber through forty three-foot by four-foot ports placed flush with the lock chamber floor in the lock walls.[158]

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[157]Ibid., pp. 6-7.

[158]Ibid., pp. 7-8.

A series of reinforced concrete struts, measuring five feet by six feet and placed flush with the lock floor, connect the land, intermediate, and river walls. These struts, designed on the basis of the work conducted by L. B. Feagin at Lock No. 26, prevent relative movement of the lock walls. The remainder of the lock floor is paved with eighteen-inch thick concrete slabs provided with six-inch pressure relief holes at ten-foot intervals.[159]

The upper miter gates are twenty-seven feet high, while the lower gates measure thirty-five feet. Recesses in the lock walls contain the gate operating machinery, the Tainter valves and Tainter valve operating machinery, and manholes for electrical lines and services.[160]

The Central Control Station is located on the land wall at approximately the midpoint of the lock chamber. The thirty-three-foot tall upper guide wall is a gravity section of reinforced concrete supported on timber piles and designed to retain the esplanade fill. The lower guide wall consists of a

[159] Ibid., p. 7.

[160] Ibid.

twenty-three-foot tall reinforced concrete section atop a riprap-filled timber crib.[161]

Continuous steel sheet pile cutoff walls or diaphragms beneath the lock walls and sills prevent water from flowing beneath the structure and eroding the foundation sands. Additional erosion protection includes a two-foot thick concrete apron extending downstream from the intermediate wall, riprap-filled timber cribs adjacent to the river side of the intermediate wall, and derrick stone protection along the riverside of the lower guide wall. The upper end of the lock is protected from scour by a riprap-covered mattress around the upper end of both the river and intermediate walls and derrick stone protection along the upper guide wall.[162]

United Construction began work on Lock No. 25 in early November 1935. The lock site, located on the Illinois side of Bradley Island, was susceptible to flooding, which forced the contractor to build a considerable portion of the esplanade fill at the beginning of the contract. The office buildings for the

[161] Ibid.

[162] Ibid., pp. 8-9.

contractor and Corps of Engineers, shops, commissary buildings, and storage facilities were constructed atop this fill.[163]

At the onset of the work United Construction attempted to obtain laborers from the local relief rolls. This effort failed to provide sufficient workers, and the contractor resorted to the use of union labor to fill out his crews. Because the work site was located in a rural area the prevailing wage rates were set significantly lower than those at Lock and Dam No. 26, which was considered part of the St. Louis metropolitan area. Common laborers at Lock and Dam No. 25 earned fifty cents per hour, more than seventeen cents less than their fellow workers downriver.[164]

United Construction began work by clearing Bradley Island and providing the fill required to build the storage and materials yard. Construction of the 1,150-foot roadway trestle connecting the island to the mainland began in mid-November 1935. By mid-February 1936 all of the concrete piles for this trestle had been placed; however, an ice flow at the end of the month destroyed most of this work and forced the Corps of Engineers to rebuild the roadway with dredged fill and a short trestle. The

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[163]Ibid., p. 27.

[164]Ibid., p. 30.

Corps completed placement of the fill by early April 1936. Work began on the five-span trestle in mid-November 1936, and was completed in early March 1937.[165]

Cofferdam construction began in mid-November 1935 and was completed in early March 1936. Unwatering operations began in late February 1936, and by the end of March the water level inside the cofferdam had been lowered to the required working level. A well point system kept the cofferdam area relatively dry during construction.[166] The cofferdam, comprised of semi-circular cell constructed of steel sheet piling, enclosed nearly nine acres. The use of short steel piles in the diaphragms connecting the cells, which averaged fifty-two feet in length and forty-one feet across, was the only deviation from full cellular construction. A fifty-two-foot long protective "fin," constructed in the same manner as the rest of the cofferdam, extended upstream from the river arm and caused a more streamlined flow around the outside of the cofferdam, thus reducing the erosion of the riverbed.[167]

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[165] Ibid., pp. 36, 46-48.

[166] Ibid., pp. 36, 45.

[167] Ibid., pp. 43-45; St. Louis District, Corps of Engineers, "Lock No. 25, Report of Cofferdam Construction and Removal" (St. Louis: Corps of Engineers, 1937), pp. 1-7. Copy on file at site.

Excavation for the upper guide wall began in early December 1935. A narrow strip of Bradley Island remained between this excavation work and the river, permitting the guide wall to be constructed with the use of a cofferdam. Pile driving for the foundations began in mid-January 1936. In late February a rise in the river flooded the excavation, and work was not resumed on this portion of the project until early July 1936. Concrete placement began in early August, and was completed by mid-November 1936.[168]

Construction within the cofferdam began in mid-March 1936, with the placing of the sheet pile cutoff wall. This work began twelve days prior to the completion of unwatering operations. Timber pile driving began in early April using standard and "special" piles of a slightly larger diameter. The "special" piles were placed in high-load areas, where their greater diameter provided additional support for the higher loads that occurred in these areas. The lock foundations include just over 9,800 piles, most between thirty-two and thirty-seven feet long, and nearly all delivered from within one hundred miles of the construction site. Pile driving was completed by mid-November 1936.[169]

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[168] "Final Report -- Lock and Dam No. 25, Volume I," pp. 36-37.

[169] Ibid., pp. 37, 51-54.

Concrete placement began at the upstream end of the intermediate wall in mid-May 1936. Several types of concrete forms were utilized. Small panels formed the base lifts of the monoliths, the sills, conduit cross-overs, and struts. Large, master panels, measuring up to forty feet high and eighteen feet wide, formed the faces of the walls and the bulkheads. Fir plywood linings were used in these forms for all surfaces exposed to view in the completed structure. Standard steel frames formed the circular portions of the culverts, while built-in-place forms were used for the lower guide wall, earth-filled recess, machinery recesses, crossover manholes, valve recesses, and other difficult forms not duplicated elsewhere in the structure. Gantry cranes handled and set all of the prefabricated forms. The Corps of Engineers noted that the "well planned system of form construction used by the contractor was no doubt responsible for a considerable saving of time in construction of the lock."[170]

The concrete mixing plant, manufactured by the Blaw-Knox Company, occupied the downstream riverward corner of the cofferdam. It consisted of two non-tilting one cubic yard mixers with attendant storage bins, scales, batchers, and water

[170] Ibid., pp. 37, 62-63. Quote on p. 63.

pumping system. The plant had a maximum capacity of sixty cubic yards per hour. Concrete was delivered to the point of placement by one of three methods; a gasoline-powered industrial locomotive with flat cars carrying two buckets, trucks carrying a single bucket, and a pumpcrete machine.[171]

Concrete was placed in the forms systematically. Alternate monolith foundations were poured first and as soon as these forms could be removed the forms for the remaining foundation monoliths were erected and the concrete placed. Large panel forms for the upper lifts of the monoliths were then erected atop the foundation lifts in such a way that the lifts could be placed alternately and the monoliths completed to grade before the sets of forms were removed. Gantry cranes and chutes placed the concrete directly into the forms. Concrete was placed in eighteen-inch layers and compacted against the forms by electrically-driven vibrators. A system of water sprinklers helped cure the concrete.[172]

Low water conditions in July and August prevented barge deliveries to the site and delayed concrete placement. Nevertheless, by mid-September 1936 concrete placement had

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[171]Ibid., pp. 63-64.

[172]Ibid., pp. 65-66.

progressed to the stage that the erection of the miter gates could begin. The Mississippi Valley Structural Steel Company plant at Melrose Park, Illinois fabricated all of the miter gate structural steel, as well as the Tainter valves, and delivered this material to the site by barge. The J. C. Theilacker Company erected the miter gates, Tainter valves, and all operating machinery, which was manufactured by the Foote Brothers Gear & Machine Corporation.[173]

The upper miter gates measured twenty-seven feet in height while the lower gates and the auxiliary lock gates measured thirty-five feet. The gates are of riveted structural steel design and consisted of top and bottom girders connected by a quoin girder, two intermediate girders, a miter girder, and nine rolled beam sections. A facing of steel buckle plates spanned the girders and beams. A strut arm, gate anchorage connections, and walkway framing were built onto the top girder. Adjustable eye-bar diagonal bracing was located across the face of the gate in the plane of the girder frame flange. Fender and seal timbers were made of white oak.[174]

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[173] Ibid., pp. 37, 69, 71.

[174] Ibid., p. 70.

Gate erection began with the setting and grouting of the pintle base and assembly. The quoin girder was then erected, followed by the bottom girder, the intermediate and miter girders, the beams, the top girder framing, the buckle plates, and finally the eye-bars. The gates were erected in a nearly open position to allow ample working space. Blocking held the bottom girder in a sloping position with the miter girder approximately 3/4-inch above its correct elevation. This allowed for sag as the gate swung in operation. After the gate was bolted, pinned, and carefully aligned and trued, all of the various elements were riveted into place. Upon completion the face joints of the gates were tested for watertightness by a sixty pounds-per-square-inch jet of water. Leaking joints and seams were welded shut. Following this operation the timber fenders were placed.[175]

Concrete placement concluded in early February 1937, and the erection of the miter gates and Tainter valves was completed by the middle of the month.[176] The J. C. Theilacker Company erected the four Tainter valves within their recesses, approximately one foot above their normal closed position. This permitted a level of adjustment prior to riveting.[177]

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[175] Ibid., pp. 70-71.

[176] Ibid., p. 37.

[177] Ibid., pp. 69-70.

In late June 1936 work began inside the cofferdam on the erection of the timber cribbing for the lower guide wall. This crib was extended through the lower arm of the cofferdam by removing the cofferdam fill and cutting rectangular holes in the steel sheet piling just large enough to accommodate the crib timbers. Lower guide wall concrete placement began in mid-July 1936 and the wall was completed by mid-January 1937. By late January 1937 work within the cofferdam had been completed, and removal of the structure began. This operation was completed by the end of March.[178]

The earth dike extends approximately 1,260 feet upstream from the end of the upper guide wall. Later contracts extended the dike to a connection with the Kings Lake Levee, approximately five miles upstream. Work on the dike began in June 1936 and was completed in February 1937. Stone paving on the river side of the dike, standard practice at the majority of the 9-Foot Channel Project installations, was completed in mid-May 1937, shortly after the inspection and acceptance of the lock by the government.[179]

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[178] Ibid., pp. 38, 45-46; "Lock No. 25, Report of Cofferdam Construction and Removal," pp. 7-9.

[179] Ibid., pp. 10, 38.

Lock No. 27 constituted the first major addition to the original 9-Foot Channel Project. The lock complex represented the final element required to secure a navigable 9-foot channel between St. Paul and St. Louis, but it was built after World War II and cannot, technically, be considered part of the 9-Foot Channel Project. Construction of Lock No. 27 presented a unique set of technical problems, since the construction site was located along an as yet unconstructed canal, and not within the river. Authorization to construct this installation was approved by Congress and signed into law in March 1945.[180]

The locks are located at the southern end of the 8.4-mile Chain of Rocks Canal, which bypassed the difficult stretch of river known as the Chain of Rocks Reach. The canal is 550 feet wide at the top, 300 feet wide at the bottom, and averages 32 feet in depth. The McWilliams Dredging Company of New Orleans constructed the canal and its levees.[181]

Construction of the locks began in July 1947. Prior to that date the Corps dredged a two-mile channel up to the lock site from the Mississippi River along the route of the proposed canal. This channel provided access to the site for the

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[180]Smyser, "Chain of Rocks Project," p. 16.

[181]Ibid.; "Biggest Lock," p. 32.

contractor's water-borne equipment and permitted excavation of the site by dredging instead of more expensive dry-land methods. A cutterhead dredge, floated to the construction site by means of the access channel, performed most of the excavation work. As it dug itself below the level of the channel the channel was plugged, and dredging continued down as near as feasible to bedrock. Pumps kept the water level in the excavation lowered as the work progressed.[182]

The material dredged from the construction site formed a 14.5-foot tall levee around the construction site, providing protection from river flooding. The dredge removed approximately sixty-seven feet of material before pumping was halted and the hole permitted to fill by means of ground water seepage. The plug to the access channel was then removed, the dredge floated out of the excavation, the plug replaced, and the water pumped from the excavation. The remainder of the excavation to bedrock was performed by clamshell buckets and cableways. Final excavation, about ten feet into the bedrock, was by drilling and blasting.[183]

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[182] "Biggest Lock," p. 30.

[183] Ibid., pp. 30-31.

Construction of the lock progressed in the fashion previously described. An industrial railroad delivered the concrete buckets to the point of placement and gantry cranes placed concrete in the forms. The American Bridge Company fabricated and erected the miter and lift gates, while the Batzli Electric Company of Minneapolis installed all of the power and control systems. The general contractor, the River Construction Corporation, consisted of a specially formed joint venture by six firms, Spencer, White and Prentis, the Turner Construction Company, the Raymond Concrete Pile Company, Winston Bros. Company, Al Johnson Construction Company, and Morrison-Knudsen Company.[184]

Dam No. 27, also known as the Chain of Rocks Dam, was constructed to correct problems with low water at Lock and Dam No. 26. Authorized in 1958, begun in early 1959, and completed in 1964, the dam assures a minimum depth of 10.5 feet of water over the lower gate sills at Lock No. 26. The fixed-crest rock dam is 3,240 feet in length, and constitutes the first complete barrier constructed across the Mississippi. It has little, if any, effect upon operations at Lock No. 27.[185]

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[184]Ibid., pp. 30-32.

[185]Mudd, "Locks & Dam No. 26," p. 9; Dobney, River Engineers, p. 116.

SUMMARY

The five Mississippi River lock and dam installations that provide a 9-foot channel in the U.S. Army Corps of Engineers' St. Louis District are significant components of one of the largest inland waterway navigation projects ever undertaken. These installations enable bulk cargoes, particularly grain and coal, to be shipped efficiently and inexpensively along a river transportation system that stretches from Minneapolis to New Orleans, with branches reaching out to Chicago, Pittsburgh, Kansas City, and Omaha.

The economic significance of the 9-foot channel locks and dams is complemented by their political significance. Conceived in the 1920s by commercial interests anxious to improve their transportation links to profitable markets, the locks and dams became transformed during the early years of the Great Depression into a massive public works program. Each project employed hundreds of workers and represented an economic bonanza for the small communities near the construction sites that supplied the workers with food, clothing, and construction materials. The adroitness with which the Corps of Engineers publicly shifted the focus of the project, from its benefits to river navigation to its employment potential as a vast public works effort, is eloquent testimony to the political sophistication of that organization. This refocusing of the project assured the Corps of funding during the first months of the New Deal, as Franklin D. Roosevelt's administration attempted to come to grips with the economic and human impacts of the Great Depression.

The 9-foot channel locks and dams are seminal developments in the technological history of United States river navigation projects. The Corps of Engineers pioneered the use of non-navigable movable dams on the Upper Mississippi. Corps designers committed themselves to the foreign technology of the roller gate, but more importantly, developed new and improved versions of the simpler and more reliable Tainter gate at such a rapid rate that by the end of the 1930s roller gates had become a passé technology.

The designs of both roller gates and Tainter gates underwent a continuous process of improvement and refinement during the course of the 9-Foot Channel Project. The development of practical submergible gates represented a major advance over the technology available at the onset of the project in the early 1930s.

A host of other technical innovations and improvements emerged from the Upper Mississippi River Project. These included the pioneering work by St. Louis District Principal Engineer L. B. Feagin into the load bearing capacities of pile-founded structures, refinements in cofferdam construction, the elimination of excess material from dam piers, the perfection of aprons and stilling basins necessary to control hydraulic leap, and improvements to the system used to empty and flood lock chambers.

The results of the massive engineering efforts conducted in the 1930s are evident in the two post-1945 structures located within the St. Louis District. Lock No. 27 and Lock and Dam No. 26R display many technical advances developed during the 1930s, including the evolution of Tainter gate design, the continued refinement of the systems used to fill and drain the lock chambers, and the pioneering testing programs designed to provide reliable data on the behavior of pile-founded structures under various loads and stresses. The use of vertical lift gates, streamlined intake and discharge manifolds, and refined construction techniques at these two sites is emblematic of the fact that lock and dam technology continued to evolve after 1940. The design, construction, and operation of the post-1940 structures in the District built upon the pioneering work conducted within the District and throughout the entire Upper Mississippi River 9-Foot Channel Project in the 1930s. These technological strides are best exemplified in Dam No. 26R's massive 110-foot Tainter gates, which may be directly traced to the continuous improvements and refinements of Tainter gate technology that occurred during the 1930s, the sophisticated and complex vertical lift gates used at the upper ends of the locks at both installations, and the rigorous testing program implemented at Lock and Dam No. 26R.

With the passage of time, and the gaining of historical perspective, the significance of the computer-aided design and testing techniques employed at Lock and Dam No. 26R may be properly evaluated. It is clear, even prior to the completion of this installation, that the application of high technology testing programs to lock and dam construction has afforded significant savings in materials and construction costs, as well as contributing to the construction of a more reliable and cost efficient structure.

Taken as a whole, the five Mississippi River lock and dam installations in the St. Louis District provide a remarkable portrait of the evolution of river navigation improvement technology since the early 1930s. The significance of these individual installations is enhanced by the important role they played in the rejuvenation of river navigation on the Upper Mississippi River and by the fact that they constitute integral components of a system of river navigation improvements extending from St. Paul, Minnesota to St. Louis, Missouri.

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